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A

SYSTEM

OF

CHEMISTRY.

IN FIVE VOLUMES.

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OF

VOLUME FIFTH.

A

SYSTEM

OF

CHEMISTRY.

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SECT. XI.

OF INDIGO.

This valuable pigment, one of the capital manufactures of America, is obtained from the leaves of different species of plants; the *indigofera argentea* or *wild indigo*, which is said to yield the finest pigment, but in smallest quantity; the *indigofera dispermu* or *Guatimala indigo*; and the *indigofera tinctoria* or *French indigo*, which yields the greatest quantity of indigo, and is therefore preferred by the planter, though its quality be inferior to the indigo obtained from the other Chap. I.

Book IV. Manufacture.

species *. For the first accurate account of the mode of preparing indigo from these plants, we are indebted to Labat †. Since his time some improvements have been introduced into the manufacture; but the mode of rearing the plants still continues the same. In the West Indies the seeds are sown in March, in trenches about a foot asunder, and the plant comes into blossom, and is fit for cutting down in May; but in south America about six months elapse before it can be cut. In the West Indies four cuttings are often obtained from the same plant in the course of a year; but in America never more than two, and often only one. The produce continually diminishes after the first cutting; so that it is necessary to renew the plants from seed every year.

The plants are cut down with sickles, and laid in strata in the *steeper*, till it is about three parts full. This is a large cistern of mason work or wood about 16 feet square. Here they are pressed down with planks, and loaded to prevent them from swimming, and covered with water to the height of four or five inches. Here they ferment; and the utmost attention is required to the process. If they be allowed to remain too long, the pigment is spoiled; and if the water be drawn off too soon, much of the indigo is lost. This fermentation, according to Le Blond, goes on best at the temperature of 80°. The water soon becomes opaque, and assumes a green colour; a smell resembling that of vo-

* Edward's *History of the West Indies*, ii. 275.; and Berthollet, *Elemens de la Teinture*, ii. 37.

† See his Account detailed by Dr Lewis in Neumann's *Chemistry* p. 435.

latile alkali is exhaled, and bubbles of carbonic acid are emitted *. When the fermentation has continued long enough, the liquor is let out into a second cistern, placed lower than the first. This cistern is called the *battery*, and is commonly about 12 feet square and four and a half deep. Here it is agitated for 15 or 20 minutes by means of levers moved by machinery, till the flocculi, beginning to separate, give it a curdled appearance. A quantity of lime water is now poured in, and the blue flocculi are allowed to subside. The lime-water is supposed to prevent putrefaction, which otherwise might endanger the pigment; and according to Le Blond, it absorbs carbonic acid, which existed in the liquid, and prevented the indigo from separating. The water is drawn off, and the pigment put to be drained in small linen bags; after which it is put into little square boxes, and allowed to dry in the shade †.

Europe was long supplied with indigo from the West Indies and America; but of late the manufacture has been introduced into Indostan, and carried on with such spirit and success as promises fair to secure to that country in future the supply of the European market ‡.

The leaves of the *indigofera* yield a green infusion to hot water, and a green powder may be precipitated from it; but unless a fermentation has taken place, neither the colour nor properties of it have any resemblance to indigo. Le Blond affirms that the contact of air is necessary to the fermentation of indigo; but his proofs are insufficient. The separation of carbonic acid

* *Jour. de Phys.* xxxviii. 141.
† Edward's *History of the West Indies*, ii. 278.
‡ See Tenant's *Indian Recreations*, ii. 142.

Book IV. is a sufficient proof that chemical decompositions are going on during the fermentation; but of what nature we are ignorant.

The *indigofera* is not the only genus of plants from which indigo may be obtained. Dr Roxburgh first drew the attention of manufacturers to the *nerium tinctorium*, a tree very common in Indostan, from the leaves of which it may be extracted in abundance. His process is shorter. The leaves are kept in a copper full of water, supported at the temperature of 160°, till they assume a yellowish hue, and the liquid acquire a deep green colour. The liquid is then drawn off, agitated in the usual manner, and the indigo thrown down by lime water *.

Indigo may be obtained also from the *isatis tinctoria*, or *woad*; a plant commonly enough cultivated in Britain, and even found wild in England †. When arrived at maturity, this plant is cut down, washed, dried hastily in the sun, ground in a mill, placed in heaps, and allowed to ferment for a fortnight. It is then well mixed, and made up into balls, which are piled upon each other, and exposed to the wind and sun. In this state they become hot, and exhale a putrid ammoniacal smell. The fermentation is promoted, if necessary, by sprinkling the balls with water. When it has continued for a sufficient time, the woad is allowed to fall to a coarse powder; in which state it is sold as a dye-stuff. By treating woad nearly in the same manner with the *indigofera*, indigo has been obtained from it

* Bancroft on *Permanent Colours*, p. 423.

† Some think that this is the plant with which the ancient Britons stained their bodies, to make them appear terrible to their enemies.

Chap. I.

by different chemists. Justi * was one of the first of these. Borth published a paper on the subject in 1754 †, Kulencamp ‡ in 1755, and Edel § a third in 1756.

Chevreul obtained, by digesting *wood* in alcohol, and evaporating the solution, *white* crystalline grains, which gradually became blue when exposed to the atmosphere, and assumed the usual appearance of indigo. These white grains he considers as indigo destitute of oxygen. Their crystallized state is remarkable ‖.

History.

The method of preparing indigo, and of applying it to the purposes of dyeing, seems to have been very early known in India; but in Europe, though it had been occasionally used as a paint ¶, its importance as a dye-stuff was not understood before the middle of the 16th century. It is not even mentioned in the *Plictho*, a celebrated work on dyeing published in Italy in 1548. The Dutch were the people who first imported it from India, and made its importance known in Europe. Even as late as the middle of the seventeenth century, its use was restricted in different countries. It was prohibited in England during the reign of Queen Elizabeth; and the prohibition was not taken off till the reign of Charles II. It was prohibited also in Saxony. In the edict it is spoken of as a corrosive substance, and called *food for the Devil*. Colbert restricted the French dyers to a certain quantity of it **. Soon after its importance began to be generally understood, it was

* Schreber's *Sammlungen*, i. 68.
† In the *Halle Newspaper*.
‡ Schreber's *Samml.* viii. 448.
§ *De Indo Germanico ex Glasto.*
‖ *Jour. de Phys.* lxvi. 373.
¶ Plinii, Lib. xxxv. c. 6.
** See Bancroft on *Permanent Colours*, and Berthollet on *Dyeing*.

Book IV. cultivated in Mexico and the West Indies wit success that the indigo from these countries was j red to every other: but within these few years tl Indian indigo, owing entirely to the enlightened tions of some of our own countrymen, has recove character, and is now imported in considerable ‹ ties to Britain.

Properties. Indigo is a fine light friable substance of a dee colour. Its texture is very compact, and the sh its surface varies according to the manner in w has been prepared. The principal tints are coppe let, and blue; the lightest indigo is the best: bı always more or less mixed with foreign substance ly owing, doubtless to the carelessness of the pı tion, and partly to the bodies which the plant c ing indigo yields to water. From the analysis oi man, to whom we are indebted for one of the mo: plete treatises on the properties of indigo which appeared, the purest indigo which he could procı composed of the following constituents:

47	pure indigo
12	gum
6	resin
22	earth
13	oxide of iron
100*	

The earth consisted of

10·2	barytes
10·0	lime
1·8	silica
22·0†	

* Bergman, v. 36. † Ibid. v. 33.

But in all probability the earth differs in different specimens; for Proust found magnesia in considerable quantity in the specimens which he examined *. The 47 parts of blue pigment are alone entitled to the name of indigo; and to them therefore we shall confine our attention in this Section.

Cheuvreul has lately published the result of his experimens on Guatimala indigo, which shows that the indigo of commerce is a still more complex substance than Bergman found it.

Constituents of common indigo.

Hot water digested on indigo became yellow. This liquid being distilled gave out ammonia and let fall a greenish matter which became blue upon exposure to the air, and possessed the properties of indigo. After this matter has separated, flocks precipitated of a green colour, to which Chevreul has given the name of *green matter*. It is scarcely soluble in water, but dissolves in alkaline leys and becomes reddish. When the alkali is saturated by an acid the colour becomes green, and when the liquid is concentrated the green matter precipitates in flocks. Alcohol dissolves it and becomes reddish; but when spread thin upon any substance it still looks green. Alcohol being poured into the water from which the green matter had precipitated, a substance fell of a brownish yellow colour and a bitter and astringent taste, and which burnt on coals, emitting the odour of empyreumatic vinegar.

The indigo thus treated was digested in alcohol. The alcohol dissolved; 1. *green matter*; 2. *red matter*; 3. *indigo*. The *red matter* agrees with the *green* in all

* Nicholson's *Journal*, iii. 325.

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its properties except colour. The colour does change by solution in alkaline leys and alcohol.

The indigo in the third place was treated with n atic acid which dissolved 1. *iron*; 2. *carbonate of l* 3. *red matter*.

The following Table exhibits the substances t from Guatimala indigo by these processes, and of sequence its composition.

Water	ammonia	
	disoxygenized indigo...	12
	green matter	
	bitter matter	
Alcohol	green matter.............	30
	red matter	
	indigo	
Muriatic acid	red matter	6
	carbonate of lime	2
	oxide of iron and alumina	2
	silica......................	3
	pure indigo..............	45
	Total	100

All indigos do not yield the same substances no same proportions. In some the *green matter* h brown colour *.

Action of water.

Indigo is a soft powder, of a deep blue inclini purple, without either taste or smell. It undergoe change though kept exposed to the air. Water not dissolve any part of it, nor produce any change it. Bergman however found, that indigo, when long under water, underwent a kind of putrefactio

* Chevreul, *Jour. de Phys.* lxv. 309.

at least exhaled a fetid odour *. When heat is applied to indigo it emits a bluish red smoke, and at last burns away with a very faint white flame, leaving behind it the earthy parts in the state of ashes †. The purple smoke, as Chevreul ascertained, crystallizes in needles, and is indigo unaltered.

Neither oxygen nor the simple combustibles have any effect upon indigo, except it be in a state of solution; and the same remark applies to the metallic bodies.

Of alkalies.

The fixed alkaline solutions have no action on indigo, except it be newly precipitated from a state of solution. In that case they dissolve it with facility. The solution has at first a green colour, which gradually disappears, and the natural colour of the indigo cannot be again restored. Hence we see, that the alkalies when concentrated decompose indigo ‡. Pure liquid ammonia acts in the same way. Even carbonate of ammonia dissolves precipitated indigo, and destroys its colour; but the fixed alkaline carbonates have no such effect §.

Earths.

Lime-water has scarcely any effect upon indigo in its usual state; but it readily dissolves precipitated indigo. The solution is at first green, but becomes gradually yellow. When the solution is exposed to the air, a slight green colour returns, as happens to the solution of indigo in ammonia; but it soon disappears ‖. The effect of the other alkaline earths upon indigo has not hitherto been tried; but it cannot be doubted that they would act nearly as lime-water, but with more

* *Opus.* v. 29.
† Ibid. p. 31.
‡ Ibid. v. 24.
§ Ibid.
‖ Ibid. 25.

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energy. The other earths seem to have but little action on indigo in any state.

Acids.

The action of the acids upon indigo has been examined with most attention, and it certainly exhibits the most important phenomena.

Sulphuric acid.

When diluted sulphuric acid is digested over indigo, it produces no effect except that of dissolving the impurities; but concentrated sulphuric acid dissolves it readily. One part of indigo, when mixed with eight parts of sulphuric acid, evolves heat, and is dissolved in about 24 hours. The solution of indigo is well known in this country by the name of *liquid blue*. Bancroft calls it *sulphate of indigo*. While concentrated, it is opaque and black; but when diluted, it assumes a fine deep blue colour, and its intensity is such, that a single drop of the concentrated sulphate is sufficient to give a blue colour to many pounds of water †.

Effect of reagents on the sulphate.

Bergman ascertained the effect of different reagents on this solution with great precision. His experiments threw light, not only on the properties of indigo, but upon the phenomena that take place when it is used as a dye-stuff. The following is the sum of these experiments:

1. Dropt into diluted water. No change.

2. Dropt into sulphurous acid. Colour at first blue, then green, and very speedily destroyed.

3. In weak nitric acid it experiences no change.

4. In muriatic acid. No change.

5. In weak tartaric acid. Becomes gradually green,

* *Opusc*, v. 25.

† Bergman, v. 7.

and in 144 hours had assumed a very pale yellow colour. Colour not restored by alkalies. Chap. I.

6. In vinegar. Becomes green, and in four weeks the colour disappeared.

7. In weak potash. Becomes green and then colourless.

8. In weak carbonate of potash. The same changes, but more slowly. If the solution be very weak, the colour of the indigo is not destroyed.

9. Soda. The same as potash.

10. In ammonia and its carbonate. Colour becomes green, and then disappears.

11. In a weak solution of sulphate of soda. Colour after some weeks becomes green.

12. In nitre, common salt, and sal ammoniac. No change.

13. In tartrate of potash. Became green and then colourless.

14. In a solution of sugar. Became green and at last yellowish.

15. In alum. No change.

16. In sulphate of copper. No change.

17. In sulphate of iron. Colour became green, and in three weeks disappeared.

18. In the sulphurets. Colour destroyed in a few hours.

19. Realgar, white oxide of arsenic, and orpiment, produced no change.

20. Black oxide of manganese destroyed the colour completely.

21. In the infusion of madder. Colour became green, and at last yellow.

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22. In the infusion of woad. The same changes, more speedily *.

Blue colour of indigo owing to oxygen.

From these experiment, it is obvious that all th substances which have a very strong affinity for oxy give a green colour to indigo, and at last destroy Hence it is extremely probable, that indigo becon green by giving out oxygen. Of course it owes its b colour to that principle. This theory was first sugge ed by Mr Haussman, and still farther confirmed Berthollet †. Now it is only when green that it is i state capable of being held in solution by lime, all lies, &c. in which state it is applied as a dye to clo The cloth, when dipt into the vat containing it: th dissolved, combines with it, and the blue colour is stored by exposure to the atmosphere. It may be stored equally by plunging the cloth into oxymuria acid. Hence the restoration cannot but be ascribed oxygen. Hence then the reason that sulphurous ac the vegetable acids, sulphate of iron, give sulphate indigo a green colour.

From these experiments, we see also that the colc of indigo is destroyed by the addition of those substa ces which part with oxygen very readily, as the bla oxide of manganese. In that case the indigo is destro ed, for its colour cannot be again restored. When t sulphate of indigo is poured into boiling water, it a fords a green-coloured solution; but with cold water deep blue solution. What is called smoking sulphu

* Bergman, v. 8.

† See *Jour. de Phys.* 1788; Berthollet's Notes on *Poërner sur l'Art la Teinture*, p. 170; and Berthollet on *Dyeing*.

acid dissolves indigo much more readily than the pure acid, and evolves much more heat during the solution. *Bucholz* has shown, that by boiling sulphur in pure sulphuric acid, it acquires the property of dissolving indigo as readily as the smoking acid *.

Chap. I.

Action of nitric acid.

Nitric acid attacks indigo with great violence; the evolution of abundance of heat and nitrous gas. When of the specific gravity 1·52, it even sets fire to indigo. This fact was discovered by Mr Woulfe. He communicated it to Rouelle, who exhibited it in his lectures. Sage first published an account of it †. When the acid is diluted, the action is still violent, unless the proportion of water be considerable. Mr Hatchett poured upon 100 grains of indigo an ounce of nitric acid diluted with an equal quantity of water. The action was so rapid, that he found it necessary to add another ounce of water. When the effervescence had nearly subsided, the liquid was placed on a sand bath for some days, and evaporated to dryness. Water poured upon the residuum dissolved a considerable portion of it, and formed a beautiful deep yellow solution of an intense bitter taste. This solution contains only a very small portion of oxalic acid; but with a solution of isinglass it forms a copious yellow insoluble precipitate, and of course contains a portion of artificial tannin. With ammonia, crystals precipitate, consisting of *bitter principle* combined with ammonia ‡.

Forms tannin,

Bitter principle,

When four parts of nitric acid are boiled upon one

* Gehlen's *Jour.* iii. 1. † Proust, Nicholson's *Jour.* iii. 328.

‡ Hatchett's Additional Experiments on Artificial Tannin, *Phil. Trans.* 1805.

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part of indigo, the pigment soon loses its colour, and is dissolved. The solution becomes yellow, and a thin layer of a resinous matter appears on the surface. If the process be now stopt, the resinous matter becomes firm by cooling. If this matter be removed, and the solution evaporated to the consistence of honey, redissolved in hot water and filtered, potash throws down yellow spicular crystals, consisting of *bitter principle* combined with potash. These crystals have the curious property of detonating with a purple light when wrapt up in paper and struck with a hammer; the resin, by treating it with fresh nitric acid, may be converted into the same bitter principle. If the process be stopt sooner than the point mentioned above, yellow crystals are obtained, which are more soluble in water, and which sublime in white needles, having all the properties of benzoic acid. These curious facts were ascertained by Fourcroy and Vauquelin *.

And benzoic acid,

Thus it appears, that by treating indigo with nitric acid, it is converted into tannin, oxalic acid, benzoic acid, and *bitter principle*.

Action of other acids,

Muriatic acid does not act upon indigo in its common state, but it readily dissolves indigo precipitated from the sulphate, and forms a blue-coloured solution. The same phenomena are exhibited by the phosphoric, acetic, tartaric acids, and probably by all except the acid supporters †.

Oxymuriatic acid destroys the colour of indigo as readily as nitric acid and obviously for the same reason ‡.

* *Phil. Mag.* xxiii. 256. † Bergman, v. 22. ‡ Ibid.

Chap. I.

Alcohol dissolves a small proportion of indigo, but it gradually precipitates again unless *red matter* be present, in which case the solution is permanent *.

Indigo is not acted upon by ether or oils, at least if the experiments of Bergman be accurate †.

Fermentation.

When indigo is mixed up with bran, woad, and other similar substances which readily undergo fermentation, it assumes a green colour during the fermentation, and is then easily dissolved by lime or potash. It is by this process that it is usually rendered proper for dyeing.

Action of heat.

When indigo is distilled, it yields products different from any other vegetable substance, if the accuracy of Bergman is to be trusted. He distilled 576 grains in a small retort connected with a pneumatic apparatus. He obtained the following products:

19 grains	carbonic acid gas
173 ——	of a yellow acid liquid containing ammonia
53 ——	oil
331 ——	charcoal
576 ‡	

He observed no other gas but carbonic acid. The experiment ought to be repeated: if it prove true, no other vegetable substance agrees with it in this respect except gallic acid. The oil was black, and had the smell of tobacco. It dissolved readily in alcohol. The quantity of charcoal appears enormous; but Bergman's experiment was made with common indigo; therefore

* Chevreul, *Jour. de Phys.* lxv. 309.
† *Opusc.* v. 35.
‡ Bergman, v. 35.

Book IV. 158 grains of earth and iron are to be subtracted from the sum. This decomposition indicates the presence of oxygen, carbon, hydrogen, and azote in indigo. The proportion of the two first constituents is uncommonly great.

Chevreul lately subjected common indigo to distillation. The products obtained were, 1. ammoniacal water. 2. Sulphur, probably combined with oily hydrogen. 3. A thick brown oil containing carbonate and acetate of ammonia. 4. Prussiate and hydroguretted sulphuret of ammonia. 5. A purple substance crystallized in silky threads on the dome of the retort. It was pure indigo. 6. A bulky charcoal yielding prussic acid when coloured with potash. 7. Gases not examined.

Such are the properties of indigo, as far as they have been ascertained. To descant on its importance is quite unnecessary. It is perhaps the most valuable, and certainly the most permanent, of all the dye-stuffs.

SECT. XII.

OF GLUTEN.

Extraction. If wheat flour be kneaded into paste with a little water, it forms a tenacious, elastic, soft, ductile mass. This is to be washed cautiously, by kneading it under a small jet of water till the water no longer carries off

any thing, but runs off colourless; what remains behind is called *gluten*. It was discovered by Beccaria, an Italian philosopher, to whom we are indebted for the first analysis of wheat flour *.

Properties.

1. Gluten, when thus obtained, is of a grey colour, exceedingly tenacious, ductile, and elastic, and may be extended to twenty times its original length. When very thin, it is of a whitish colour, and has a good deal of resemblance to animal tendon or membrane. In this state it adheres very tenaciously to other bodies, and has often been used to cement together broken pieces of porcelain. Its smell is peculiar. It has scarce any taste, and does not lose its tenacity in the mouth. When exposed to the air, it assumes a brown colour, and becomes as it were covered with a coat of oil.

When exposed to the air, it gradually dries; and when completely dry, it is pretty hard, brittle, slightly transparent, of a dark brown colour, and has some resemblance to *glue*. It breaks like a piece of glass, and the edges of the fracture resemble in smoothness those of broken glass; that is to say, it breaks with a *vitreous* fracture.

Soluble in water.

Fresh gluten imbibes water, and retains a certain quantity of it with great obstinacy. To this water it owes its elasticity and tenacity. When boiled in water it loses both these properties.

2. When fresh gluten is macerated for a considerable time in cold water, the liquid becomes opaque, and contains small films suspended, which do not soon subside. By repeated filtrations it becomes transparent; but it

* *Collect. Academ*, x. 1.

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holds in solution a little gluten, which renders it frothy, and gives it the property of precipitating when mixed with oxymuriatic acid or the infusion of nutgalls. Thus gluten is to a certain extent soluble in cold water. When the water is heated, the gluten separates in the state of yellow flakes *.

When kept moist, it very soon begins to decompose, and to undergo a species of fermentation. It swells, and emits air-bubbles, which Proust has ascertained to consist of hydrogen and carbonic acid gases †. It emits also a very offensive odour, similar to what is emitted by putrefying animal bodies. Cadet kept gluten in a vessel for a week in a damp room. Its surface became covered with byssi, the fermentation just mentioned had commenced, and the odour was distinctly acid. In 24 days, on removing the upper crust, the gluten was found converted into a kind of paste, of a greyish white colour, not unlike bird-lime. In that state he gave it the name of *fermented gluten* ‡. If the gluten be still left to itself, it gradually acquires the smell and the taste of *cheese*. This curious fact was first ascertained by Rouelle junior. In that state it is full of holes, and contains the very same juices which distinguish some kinds of cheese. Proust ascertained that it contains ammonia and vinegar; bodies which Vauquelin detected in cheese: and ammonia robs both equally of their smell and flavour §.

Fermented gluten.

* Fourcroy and Vauquelin, *Annales de Mus. d'Hist. Nat.* No. xxxvii. p. 3.

† *Jour. de Phys.* lvi. 108.

‡ *Ann. de Chim.* xli. 315.

§ Proust, *Jour. de Phys.* lvi. 100.

Chap. I.

Fourcroy and Vauquelin have examined the changes which gluten sustains when left for some months to putrify under water. When left in that liquor, at the temperature of 54°, it swells, becomes sour and fetid, and rises to the surface, giving out carbonic acid. The water acquires the property of giving out a red colour to paper stained with litmus. The fixed alkalies disengage ammonia, and oxymuriatic acid and infusion of nutgalls throw down a precipitate, indicating the presence of gluten in solution. When sugar is dissolved in this water, the liquid assumes the properties of vinegar, without fermentation or contact of the atmosphere. If the gluten be put again into water at the same temperature, the fermentation goes on, carbonic acid is disengaged, and the liquid slightly reddens litmus paper. The reagents indicate the presence of gluten and ammonia. The gluten, which forms a pellicle on the surface of the liquid, becomes first purple coloured, and then blackish grey, and exhales the fetid odour of putrefying mucous membranes. The water is now blackish; it gives a brown colour to nitrate of silver, blackens nitrate of mercury, becomes milky, and loses its smell when mixed with oxymuriatic acid, and is not precipitated by infusion of nutgalls. After three months putrefaction, the gluten was greatly diminished; it had a brown colour, and exhaled only a weak smell. When dried it formed lumps, which emitted the odour of the earth from a burial ground. They softened under the fingers, and burned like fat. In alcohol it partly dissolved, leaving behind it a substance which resembled woody fibre in its properties *. Thus by putrefac-

* *Ann. de Mus. d'Hist. Nat.* No. xxxvii. 4.

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tion gluten is converted into *carbonic acid*, *ammonia*, a *fatty matter*, and a substance analogous to *woody fibre*.

Action of alcohol.

3. Fresh gluten does not sensibly dissolve in alcohol, which even throws down fresh gluten from water; yet in certain cases this liquid forms a solution of gluten in very small proportion. I poured two ounces of alcohol, of the specific gravity 0·837, upon 100 grains of pearl barley ground to a coarse powder, and allowed it to stand untouched for two years. On evaporating the liquid, it left behind it a yellow matter, which partly resembled an oil. Alcohol digested upon this substance took up the yellow matter and left *gluten*, easily recognizable by its properties. On trying the same experiment with wheat fluor, no gluten was taken up, but only a yellow matter, which possessed the properties of *bitter principle*.

When the *fermented* gluten of Cadet is triturated with a little alcohol into a mucilage, and then mixed with a sufficient quantity of that liquid, a portion of it is dissolved. This solution constitutes an excellent varnish, possessed of considerable elasticity. It may be spread over paper or wood; and when dry resists other bodies as well as most varnishes. In this state, too, it may be employed to cement china; and triturated with paints, especially vegetable colours, it forms a very good ground. When this solution is mixed with a sufficient quantity of lime, it forms a very good lute; and bits of linen dipt in it adhere very strongly to other bodies *.

4. Ether does not sensibly dissolve gluten.

* Cadet, *Ann. de Chim.* xli. 316.

Chap. I.

5. Acids act upon gluten differently according to the peculiar properties of each.

Acids,

Concentrated acetic acid dissolves it readily in considerable quantity, and without altering its nature. The solution is muddy, but permanent; and the gluten may be thrown down by means of alkalies. This acid dissolves the fermented gluten of Cadet; and the solution may be substituted for the solution in alcohol as a varnish; but it does not answer to mix it with colours *.

Concentrated sulphuric acid renders it violet coloured, and at last black; inflammable air escapes, and charcoal, water, and a portion of ammonia, are formed †. When nitric acid is poured on it, and heat applied, there is a quantity of azotic gas emitted, as Berthollet discovered; and by continuing the heat, some little oxalic acid is formed ‡, and likewise malic acid, while a number of yellow-coloured oily flakes make their appearance in the solution.

Muriatic acid dissolves gluten with facility when its action is assisted by heat. When gluten is placed in oxymuriatic acid it softens, and seems to dissolve, but soon coagulates again into yellow-coloured flakes, which become transparent and greenish coloured by drying. When heated, they exhale oxymuriatic acid, and assume the appearance of common gluten §. This acid has the property of precipitating gluten from water in the state of yellowish white flakes.

Alkalies.

6. Alkalies dissolve gluten when they are assisted

* Cadet, *Ann. de Chim.* xli. 316.

† Fourcroy, vii. 304.

‡ Vauquelin, *Ann. de Chim.* vi. 278.

§ Fourcroy and Vauquelin, *Ann. de Mus. d'Hist. Nat.* No. xxxvii. 3.

Book IV. by heat. The solution is never perfectly transparent. Acids precipitate the gluten from alkalies, but it is destitute of its elasticity *. Alkalies, when much concentrated, form with it a kind of soap, converting it into oil and ammonia; which last is dissipated during the trituration.

Nutgalls. 7. Gluten is precipitated from water, and from some of its other solutions, by the infusion of nutgalls. The colour of the precipitate is usually yellowish brown, and it does not dissolve though the solution be heated.

8. The action of the metallic oxides and their salts upon gluten has not been tried.

It has a strong affinity for the colouring matter of vegetables, and likewise for resinous bodies.

Heat. 9. When moist gluten is suddenly dried, it swells amazingly. Dry gluten, when exposed to heat, cracks, swells, melts, blackens, exhales a fetid odour, and burns precisely like feathers or horn. When distilled, there come over water impregnated with ammonia and an empyreumatic oil; the charcoal which remains is with difficulty reduced to ashes.

10. The properties of this substance clearly point out a resemblance between it and animal matter; and the phenomena of its fermentation and destructive distillation show us that oxygen, hydrogen, carbon, and azote, are constituents of it. Proust first observed that the vapour which it emits, while fermenting, blackens silver and lead, and of course contains sulphur.

11. Like all other vegetable principles, gluten is susceptible of various shades of properties, which consti-

* Fourcroy.

tute so many species. In wheat flour it occurs in the greatest abundance, and from it we can extract it with the greatest ease: But the sagacity and industry of Rouelle and Proust have detected its presence in many other vegetable substances. Rouelle found it in the leaves of all the vegetable substances which he examined. The exactness of this opinion was called in question by Fourcroy, who treated the experiments of Rouelle with contempt; but it has been lately examined, and confirmed by very decisive experiments of Proust.

Green fecula contain gluten.

When the juice of cabbage leaves, cresses, scurvy-grass, and other similar plants, is extracted by pressure and passed through a cloth, it still continues far from transparent. Its muddiness is owing to a fine soft silky green powder suspended in it, which subsides to the bottom so slowly as to take at least a week before it is deposited. This green powder has been distinguished by the name of the *green fecula* of plants. Rouelle first examined it with attention, and ascertained its properties; and the subject has been carried still farther by Proust. The slowness with which it subsides, shows that its specific gravity does not differ much from that of water. When once it has fallen, it is insoluble. This substance consists chiefly of three principles: 1. A green matter to which it owes its colour, separated by digestion in alcohol, and which possesses the properties of a *resin*. 2. A substance which consists chiefly of *woody fibres*, and which is left behind when the fecula is digested in potash. 3. A species of gluten, which constitutes the greatest part of it, and to which it owes its characteristic properties.

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When the juice of the plants is exposed to a heat of about 130°, the green fecula undergoes a kind of coagulation, concreting into large flakes, which subside very quickly. At this temperature albumen is not altered by heat. This is the method commonly taken to *clarify* these juices. We see from it, that the fecula was united to the water by a very small force, which the addition of heat weakened sufficiently to enable the gluten to cohere. This coagulation by heat takes place how diluted soever the juices are with water; which is by no means the case with albumen. It is thrown down also by the addition of a little alcohol, by all acids, by ammonia, by sulphureted hydrogen gas, or by throwing into the liquid crystals of carbonate of potash, magnesia, common salt, muriate of potash, nitre, sal ammoniac, &c.

When separated from water it soon dries, and becomes elastic, and somewhat of the appearance of horn; and in that state is scarcely softened by hot water. When treated like gluten, it gradually acquires the cheesy taste and smell. When kept under water it very soon begins to putrefy, and exhales a gas which blackens silver and solutions of lead. This speedy putrefaction in stagnant water takes place when flax and hemp are steeped. These substances contain green fecula in their rind, and the putrefaction occasions the separation of the whole, which could not otherwise be accomplished. The water which has been allowed to remain for a whole year over green fecula contains sulphureted hydrogen, carbonate of ammonia, and gluten seemingly held in solution by the ammonia. The

stench of putrefaction still continues even after the water has been boiled *.

Chap. I.

Plants containing gluten.

12. The number of plants containing gluten is very considerable. Proust found it in acorns, chesnuts, horse-chesnut, rue, barley, rye, peas, and beans; and in apples and quinces. He found it also in the leaves of cabbage, sedums, cress, hemlock, borage, saffron, &c.; in the berries of the elder, the grape, &c.; in the petals of the rose, &c †. It occurs also in several roots: Proust could find none in the potato.

13. Gluten must be considered as one of the most useful of the vegetable principles. It constitutes an essential ingredient in wheat, and is the substance which renders flour of wheat so fit for forming bread. It seems also to constitute the essential part of yest. Its uses as a varnish, a ground for paint, &c. pointed out by Cadet, likewise deserve attention.

SECT. XIII.

OF ALBUMEN.

Albumen is the term by which chemists have agreed to denote the *white of egg*, and all glary tasteless substances which, like it, have the property of coagulating into a white, opaque, tough, solid substance, when

* Proust, *Jour. de Phys.* lvi. 97.   † Id. Ibid.

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heated a little under the boiling point. This substance forms a constituent of many of the fluids of animal bodies; and when coagulated, it constitutes also an important part of their solids. Substances analogous to it had been noticed by chemists in the vegetable kingdom. Scheele affirmed, as early as 1780, that the greater number of plants contained a substance analogous to curd *. Fourcroy, about the year 1790, announced the existence of albumen in a variety of plants †; but Proust has since shown, that the substance which he took for albumen, and which had been already examined by Rouelle, was not possessed of the properties which characterise that animal matter ‡. But Vauquelin has lately discovered albumen in abundance in the juice of the papaw tree; so that its existence as a vegetable principle cannot be disputed.

Found in papaw juice.

The *papaw tree*, the *carica papaya* of botanists, grows in Peru, &c. and in the Isle of France, where the milky juice that exudes from it is said to be employed with efficacy against the *Guinea worm*. Two specimens of this juice were brought from that island to Paris by Charpentier de Cossigny. In the one, the juice had been evaporated to dryness, and was in the state of an extract; in the other, the juice was preserved by being mixed with an equal bulk of rum. Both were subjected to a chemical analysis by Vauquelin. The first was of a yellowish white colour, and semitransparent. Its taste was sweetish. It had no smell, and was pretty solid; but attracted moisture

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* Scheele, ii. 55.

† *Ann. de Chim.* iii. 259.

‡ *Jour. de Phys.* lvi. 97

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when kept in a damp place. The second was reddish brown, and had the smell and taste of boiled beef. When the first specimen was macerated in cold water, the greatest part of it dissolved. The solution frothed with soap. The addition of nitric acid coagulated it, and rendered it white; and when boiled, it threw down abundance of white flakes. These flakes were coagulated albumen *.

Other specimens of this juice, both in the liquid and dried state, have been examined more recently by Vauquelin †, and likewise by Cadet ‡.

Properties.

The essential characters of albumen are the following:

1. In its natural state it is soluble in water, and forms a glary limpid liquid, having very little taste; which may be employed as a paste, and which forms a very shining varnish.

2. The solution is coagulated by acids, pretty much in the same way as milk is coagulated by the same reagents.

3. When not too much diluted, it is coagulated also when heated to the temperature of 176°.

4. Albumen dissolved in water is precipitated in the state of brown flakes by the infusion of tan.

5. The solution is equally coagulated when mixed with alcohol.

6. Albumen is precipitated from water in the state of white powder by the salts of most of the white metals; such as silver, mercury, lead, tin, &c.

* *Ann. de Chim.* xliii. 267.
† Ibid. xlix. 295.
‡ Ibid. xlix. 250, and l. 319.

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The juice of the papaw possessed all these properties *. It therefore contained albumen. In few other vegetable productions has this substance been yet found in such abundance, or in a state in which its properties were so decidedly characteristic; but the resemblance between the curd of milk and albumen is very close, as we shall see afterwards. Now Proust has ascertained that *almonds*, and other similar kernels from which *emulsions* are made, contain a substance which has the properties of curd †.

Albumen when burnt emits ammonia; and when treated with nitric acid, yields azotic gas. It evidently, then, contains azote. But as it is more properly an animal than a vegetable substance, I shall defer giving any farther account of its properties till I come to treat of animal bodies.

And in other plants.

The papaw is not the only plant which contains this vegetable albumen in abundance. The juice of the fruit or pods of the *hibiscus esculentus* contains it also in such quantity that it may be employed, as I am informed by Dr Clarke of Dominica, as a substitute for whites of eggs in clarifying the syrup of the sugar cane. By the same gentleman I have been informed of a curious property which the green juice of the papaw possesses. Meat (even salt meat), when well rubbed with it, becomes in about an hour quite tender. People are not fond of eating meat which has been made tender by this means, though Dr Clarke assures me he has eaten it without any bad effect whatever.

* Vauquelin, *Ann. de Chim.* xliii. 267.
† *Jour. de Phys.* lxi. 88.

Chap. I.

Found in the pollen of the phœnix dactilifera.

Fourcroy and Vauquelin have lately found, in the pollen of the *phœnix dactilifera* or date tree, a substance which possesses properties analogous to *albumen*. By Vauquelin, in his recent analyses, it is usually denominated *vegeto-animal principle*.

When the pollen of this tree was digested in cold water, and the liquid evaporated, a brown substance remained. A portion of this extract dissolved in alcohol; another portion in water; and a third remained insoluble in both. The portion soluble in water, when mixed with ammonia, let fall a quantity of *phosphate of magnesia*. The solution, concentrated by evaporation, formed crystals of malate of ammonia. After the separation of these a substance still remained, which formed a copious precipitate with infusion of nutgalls, and possessed other properties similar to albumen *.

SECT. XIV.

OF FIBRIN.

That peculiar substance which constitutes the fibrous part of the muscles of animals has been called *fibrin* by chemists. A substance resembling it, as it exists in the

* Fourcroy and Vauquelin, *Annales de Museum d'Histoire Naturelle*, i. 417.

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blood, has been detected by Vauquelin in the juice the papaw tree; the same juice which contained alb men in such plenty. Fibrin then must be ranked mong vegetable substances.

Found in the papaw.

When the juice of the papaw is treated with wat the greatest part dissolves; but there remains a su stance insoluble, which has a greasy appearance. softens in the air, and becomes viscid, brown, and mitransparent. When thrown on burning coals melted, let drops of grease exude, emitted the noise meat roasting, and produced a smoke which had t odour of fat volatilized. It left behind it no residu This substance was the *fibrin*. The resemblance b tween the juice of the papaw and animal matter is close, that one would be tempted to suspect some i position, were not the evidence that it is really the jui of a tree quite unexceptionable *.

The properties of fibrin are the following:

Properties.

1. It is tasteless, fibrous, elastic, and resembles gl ten.

2. It is insoluble in water and in alcohol.

3. It is not dissolved by diluted alkalies.

4. But acids dissolve it without difficulty.

5. With nitric acid it gives out much azotic gas.

6. When distilled it yields much carbonate of am monia and oil.

7. It soon putrefies when kept moist, becomes gree but does not acquire any resemblance to cheese.

A fuller description of this substance must be rese ved for the next Book, as it belongs rather to the ar mal than vegetable kingdom.

* *Ann. de Chim.* xliii. 267.

SECT. XV.

OF THE BITTER PRINCIPLE.

MANY vegetable substances have an intensely bitter taste, and on that account are employed in medicine; by brewers, &c. This is the case with the wood of the *quassia amara* and *excelsa*, the common *quassia* of the shops; with the roots of the *gentiana lutea*, common *gentian*; the leaves of the *humulus lupilus* or *hop*; the bark and wood of the *spartium scoparium* or common broom; the flowers and leaves of the *anthemis nobilis* or *chamomile*; and many other substances. Some of these bodies owe their bitter taste to the presence of a peculiar vegetable substance differing from every other, which may be distinguished by the name of the *bitter principle*.

Plants containing bitter principle.

No chemical examination of this substance has been hitherto published; nor indeed are we in possession of any method of separating it from other bodies, or of ascertaining its presence. At the same time it cannot be doubted that it possesses peculiar characters; and its action on the animal economy renders it an object of importance.

1. When water is digested over *quassia* for some time, it acquires an intensely bitter taste and a yellow colour, but no smell. When water thus impregnated is evaporated to dryness in a low heat, it leaves a brown-

Experiments on the infusion of quassia.

Book IV. ish-yellow substance, which retains a certain degree of transparency. It continues ductile for some time, but at last becomes brittle. This substance I shall consider as the bitter principle in a state of purity. If it contain any foreign body, it must be in a very minute proportion. This substance I find to possess the following properties.

1. Its taste is intensely bitter. Colour brownish yellow.

2. When heated, softens, and swells, and blackens, then burns away without flaming much, and leaves a small quantity of ashes.

3. Very soluble in water and alcohol.

4. Does not alter the colour of infusion of litmus.

5. Lime-water, barytes-water, and strontian-water occasion no precipitate. Neither is any precipitate thrown down by silicated potash, aluminated potash, or sulphate of magnesia.

6. The alkalies occasion no change in the diluted solution of the bitter principle.

7. Oxalate of ammonia occasions no precipitate.

8. Nitrate of silver renders the solution muddy, and a very soft flaky yellow precipitate falls slowly to the bottom.

9. Neither corrosive sublimate nor nitrate of mercury occasion any precipitate.

10. Nitrate of copper, and the ammoniacal solution of copper, produce no change; but muriate of copper gives the white precipitate, which falls when this liquid salt is dropt into water.

11. Sulphate and oxymuriate of iron occasion no change.

12. Muriate of tin renders the solution muddy, but

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occasions no precipitate, unless the solution be concentrated; in that case a copious precipitate falls.

13. Acetate of lead occasions a very copious white precipitate; but the nitrate of lead produces no change.

14. Muriate of zinc occasions no change.

15. Nitrate of bismuth produces no change, though when the salt is dropt into pure water a copious white precipitate appears.

16. Tartar emetic produces no change; but when the muriate of antimony is used, the white precipitate appears, which always falls when this salt is dropt into pure water.

17. Muriate and arseniate of cobalt occasion no change.

18. Arseniate of potash produces no effect.

19. Tincture of nutgalls, infusion of nutgalls, gallic acid, occasion no effect.

These properties are sufficient to convince us that the bitter principle is a substance differing considerably from all the other vegetable principles. The little effect of the different reagents is remarkable. Nitrate of silver and acetate of lead are the only two bodies which throw it down. This precipitation cannot be ascribed to the presence of muriatic acid; for if muriatic acid were present, nitrate of lead would also be thrown down. Besides, the flakes produced by nitrate of silver are too light, and indeed have no resemblance whatever to muriate of silver. The precipitate by acetate of lead is very copious. This salt is therefore the best substance for detecting the presence of the bitter principle, when we are certain that no other substance is present which throws down lead.

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Exists in other plants.

Vauquelin has lately examined the bitter princ in the fruit of the colocynth (*cucumis colocynthis*), in the root of the briony (*brionia alba*), two veget bodies which have been employed in medicine, possess strong lethargic powers. The bitter princ in these substances, as far as his experiments w possess exactly the properties of the bitter principl quassia *. It is probable also that hops, gentian, broom, contain the same bitter principle.

When alcohol is digested for some months u wheat flour, and then distilled, it leaves a yellov brown substance behind it, which possesses (as far have examined it) all the properties of the bitter p ciple of quassia.

Second species of bitter principle.

II. Besides this purest species of bitter principl is probable that several others exist in the veget kingdom, gradually approaching by their qualities to nature of *artificial tannin*. The second species is tinguished from the preceding, by the property wh it has of striking a green colour with iron, and of cipitating that metal from concentrated solutions. Chenevix separated a portion of it from coffee by following process: He digested unburnt coffee in wa and filtered the liquid. It was then treated with m riate of tin. The precipitate was edulcorated, mi with water, and treated with sulphureted hydrogen The tin was thus precipitated, and the substance v which it had been combined was dissolved by the ter. The liquid was then evaporated to dryness.

* Vauquelin, *Essais Analytiques des Racines d' Ellebore d'Hiver* *Brione*. *Ann. de Mus. d' Hist. Nat.* No. xliii. 91.

substance thus obtained possessed the following properties: Chap. I.

1. Semitransparent like horn, and of a yellow colour.

2. When exposed to the air, it does not attract moisture.

3. Soluble in water and in alcohol. The solution in water is semitransparent, and has a pleasant bitter taste. When the alkaline solutions are dropt into it, the colour becomes garnet red.

4. It is not precipitated from water by the alkaline carbonates. Sulphuric acid renders the solution brown, but produces no further change. Neither muriatic acid, nor phosphoric acid, nor the vegetable acids, produce any change on this solution.

5. The muriates of gold, platinum, and copper, occasion no change.

6. With solutions of iron it forms a fine green coloured liquid; and when concentrated, iron throws down a green coloured precipitate. Indeed it is almost as delicate a test of iron as tan and gallic acid.

7. Muriate of tin throws down a copious yellow precipitate. This precipitate, and that by iron, are soluble in all acids, but they lose their colour.

8. Neither lime nor strontian water occasion any precipitate in the aqueous solutions of this substance; but barytes water occasions a brown precipitate.

9. Gelatine occasions no precipitate *.

From the experiments of Bouillon la Grange, it appears that a substance similar to this second species of bitter principle exists in the flowers of the *arnica mon-*

* *Phil. Mag.* 1802, May, p. 350.

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tana *. There is reason for believing that the bitter principle which characterizes the following plants belongs also to this second species; *absinthium vulgare* (worm-wood), *juniperus sabinus* (sabine), *ruta graveolens* (rue), *anthemis nobilis* (chamomile), *achillea millefolium* (milfoil).

Third species.

III. The Third species may be distinguished by the name of *artificial bitter principle*, as it has been formed by the action of nitric acid on various vegetable and animal substances. It was first obtained by Haussman while examining indigo, but he mistook its nature. Welther afterwards formed it by digesting silk in nitric acid, ascertained its properties, and gave it the name of *yellow bitter principle* †; he is therefore to be considered as the real discoverer. Bartholdi afterwards procured it by treating the *white* willow with nitric acid ‡. Mr Hatchett lately obtained it during his experiments on artificial tannin, by treating indigo with nitric acid §; and about the same time Fourcroy and Vauquelin procured it by the same means, and examined its properties in detail ‖. This substance possesses the following properties ¶.

Its colour is a deep yellow, its taste intensely bitter. It is soluble both in water and alcohol, and has the property of dyeing silk, woollen cloth, and cotton, of a durable yellow colour. It crystallizes in elongated plates, and possesses many of the characters of an acid, combining readily with alkaline substances, and form-

* *Ann. de Chim.* lv. 35. † Ibid. xxix. 301. ‡ Ibid. xxxii. 187
§ *Phil. Trans.* 1805. ‖ *Phil. Mag.* xviii. 255.
¶ See the method of procuring it described in Section X.

Chap. I.

ing crystallizable salts. When potash is dropt into a concentrated solution of it, small yellow prismatic crystals are gradually deposited, consisting of bitter principle combined with potash. These crystals were examined by Welther, but it was Fourcroy and Vauquelin that ascertained their composition. They have a bitter taste, are not altered by exposure to the air, are less soluble than pure bitter principle. When thrown upon hot charcoal they burn like gunpowder, and detonate very loudly when struck upon an anvil, emitting a purple light *. Ammonia dropt into the solution of bitter principle deepens its colour, and occasions a copious deposition of fine yellow spicular crystals. These are a combination of bitter principle and ammonia †.

Fourth species.

IV. Artificial tannin itself may be considered as approaching the bittter principle in many of its properties. Its taste is always intensely bitter, and the colour of the precipitates which it throws down from the metals, is similar to what takes place when artificial bitter principle is present. It is indeed possible, that the bitter taste may be owing not to the tannin, but to a portion of artificial bitter principle which may be always formed along with the tannin; but this has not been ascertained. It is well known that the bitter taste very easily overpowers and conceals all other tastes.

* Welther, Fourcroy, and Vauquelin.

† Hatchett, *Phil. Trans.* 1805.

SECT. XVI.

OF TANNIN.

NOTWITHSTANDING the numerous experiments made upon the infusion of nutgalls, we are not in possession of a process capable of furnishing tannin in a state of purity. Hence the obscurity which still hangs over its characters. The properties of this substance, as far as known, and the different methods of procuring it hitherto proposed by chemists, have been detailed in a preceding part of this Work. In that account the labours of Bouillon la Grange *, who has added considerably to the number of facts collected by his predecessors, and modified in some particulars, the received opinions, have been omitted. His process for procuring pure tannin is as follows: Into an infusion of nutgalls, made with cold water, drop a solution of crystallized carbonate of ammonia, as long as any precipitate continues to fall. Separate the precipitate by a filter, and wash it with cold water till the liquid comes off colourless. Then digest it repeatedly in alcohol, of the specific gravity 0·817, till the liquid ceases to redden the tincture of litmus. Dry it between folds of blotting

New method of obtaining tannin.

* *Ann. de Chim.* lvi. 172.

paper. Such is the process; but no reason is assigned for considering the tannin thus procured as pure.

Its properties.

The tannin of this process is white, has a bitter taste, and reddens litmus paper. It does not melt when heated, nor does it alter, if dry, by exposure to the air. It dissolves sparingly in cold, but readily in hot water. By the action of oxymuriatic acid, it seems to be converted into gallic acid. Hence it is probable that gallic acid and tannin differ merely in the proportion of oxygen which they contain. Lime, barytes, and strontian water precipitate tannin green. The fixed alkalies deepen the colour, and prevent the tannin from acting on gelatine. It deprives several of the metallic oxides either of the whole, or of a portion, of their oxygen. When red oxide of iron is boiled in the solution of tannin, it becomes blackish brown, and combines to saturation with tannin. In like manner red oxide of lead deprives the solution of the whole of its tannin, and assumes a dark brown colour. Red oxide of mercury assumes the same colour, and produces the same effect.

With acetate of lead it forms a dark grey heavy precipitate, and the whole of the lead is abstracted from the solution. The precipitate, when first dried, is greenish, but becomes brown by exposure to the air. Copper is thrown down brown from its solutions. The precipitation is incomplete. Sulphate of manganese is thrown down green, but the precipitate becomes brown by exposure to heat. Nitrate of mercury is precipitated yellow. When the tannate of iron is dissolved in muriatic acid, barytes occasions no precipitate; a proof that it contains no sulphuric acid. These are the most important of the facts noticed by Bouillon la Grange in his Dissertation on Tannin.

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Tannin exists in a great variety of substances. T bark of many trees contain it abundantly. It is fou also in the roots, wood, and branches of many. Som times it is accompanied by gallic acid, and sometin not. The presence of this acid may be distinguisl by the action of the infusion on the salts of iron. the precipitate subside quickly, it is a proof that gallic acid is present; but if it subside very slowly, may conclude that this acid is present *.

Species of tannin.

Like most other vegetable substances, it seems to susceptible of different modifications. The follow are the different species of tannin which have b hitherto noticed.

From nutgalls.

1. Tannin from nutgalls. This is the common s cies described in this Work under the name of tann It precipitates iron black, and forms a firm insolu brown precipitate with glue. The bark of oak, most other astringent trees in this country, are suppo at present to contain this species of tannin.

Catechu.

2. The tannin which constitutes so large a prop tion of catechu forms the second species. Its pecu nature was first observed by Proust. It was afterwa more particularly examined by Mr Davy. It fo with iron an olive coloured precipitate.

Kino.

3. The tannin of *kino* constitutes a third spec This substance is obtained from different vegetab It was originally imported, as is supposed, from Afr but at present the common kino of the shops is, cording to Dr Duncan, an extract from the *cocco uvifera*, or *sea-side grape*, and is brought chiefly fi

* Berthollet, *sur la Teinture*, i. 108.

Jamaica. But the finest kino is the product of different species of *eucalyptus*, particularly the *resinifera* or brown gum tree of Botany Bay *. It is an astringent substance of a dark red colour, and very brittle. It dissolves better in alcohol than water. The solution in the latter liquid is muddy; in the former transparent, and a fine crimson if sufficiently diluted. It throws down gelatine of a rose colour, and forms with salts of iron a deep green precipitate, not altered by exposure to the air. These properties, first observed by Dr Duncan, and afterwards by Vauquelin, show that it contains abundance of tan, but in a particular state †.

Chap. I.

Sumach.

4. The fourth variety of tannin is contained in *sumach*. This is a powder obtained by drying and grinding the shoots of the *rhus coriaria*; a shrub cultivated in the southern parts of Europe. The tan, which it contains in abundance, yields a precipitate with gelatine, which subsides very slowly, and remains in the state of a white magma without consistence.

Fustic.

5. The fifth variety, according to Proust, is to be found in the wood of the *morus tinctoria*, or *old fustic* as the British dyers term it. This wood gives out an extract both to alcohol and water, which yields a precipitate with gelatine. A solution of common salt is sufficient to throw it down ‡.

Tannin affects particularly the bark of trees; but it exists also in the sap and in the wood of a considerable number, and even in the leaves of many. It is very seldom that it exudes spontaneously; yet this seems to

* Nicholson's *Jour.* vi. 234.

† *Ann. de Chim.* xlvi. 321.

‡ Proust, *Ann. de Chim.* xlii. 94.

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be the case with a variety of kino from Botany B which I have lately examined.

It has been ascertained by Mr Biggin *, that wl the barks of trees are examined at different seasons tl vary in the quantity of tan. The quantity varies with the age and size of the trees †. The greatest p portion of tan is contained in the inner bark ‡. 1 epidermis usually contains none.

The following Table exhibits the proportion of sc matter extracted by water from different vegetable su stances, and the quantity of tan contained in that sc matter, as ascertained by the experiments of Mr Da

Table of the quantity of tannin in plants.

One ounce of	Solid Matter. Grains.	T Gr
White inner bark of old oak	108	...
... young oak	111	...
... Spanish chesnut	89	...
... Leicester willow	117	...
Coloured or middle bark of oak	43	...
... Spanish chesnut	41	...
... Leicester willow	34	...
Entire bark of oak	61	...
... Spanish chesnut	53	...
... Leicester willow	71	...
... elm	—	...
... common willow	—	...
Sicilian sumach	165	...
Malaga sumach	156	...
Souchong tea	—	...
Green tea	—	...

* Phil. Trans. 1798, p. 299. † Davy, Ibid. 1803. ‡ Davy, Ib

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One ounce of	Solid Matter. Grains.	Tan. Grains.
Bombay catechu	—	... 261
Bengal catechu	—	... 231
Nutgalls	180	... 127

SECT. XVII.

OF THE EXTRACTIVE PRINCIPLE.

History.

The word *extract* was at first applied to all those substances which were extracted from plants by means of water, and which remained behind in the state of a dry mass when the water was evaporated; consequently it included gum, jelly, and several other bodies. But of late it has been confined by many to a substance which exists in many plants, and which may be obtained nearly in a state of purity, according to Hermbstadt, by infusing *saffron* in water for some time, filtrating the infusion, and evaporating it to dryness. But as the word *extract* occurs even in modern authors in its original sense, I shall rather denote this substance by the phrase *extractive principle*, to prevent ambiguity.

The difficulty of obtaining the extractive principle in a separate state, and the facility with which it alters its nature, have hitherto prevented chemists from examining it with that attention to which it is entitled. It was first particularly attended to by Rouelle; but it is to Fourcroy and Vauquelin that we are chiefly indebt-

Book IV. ed for ascertaining its characters. The dissertation of Vauquelin in the *Journal de Pharmacie*, is by far the best account of extractive matter which has hitherto appeared. Many valuable facts and curious observations were published by Hermbstadt also in his dissertation on *extract* *. But unfortunately the term has not been always taken by chemists in the same acceptation. Parmentier has lately published a dissertation on the *extracts* of vegetables taken in the loose and general sense of the word, which contains much information †.

The extractive principle possesses the following properties:

Properties. 1. Soluble in water, and the solution is always coloured. When the water is slowly evaporated, the extractive matter is obtained in a solid state and transparent; but when the evaporation is rapid the matter is opaque.

2. The taste of extractive is always strong; but it is very different according to the plant from which it is obtained.

3. Soluble in alcohol, but insoluble in ether.

4. By repeated solutions and evaporations, the extractive matter acquires a deeper colour, and becomes insoluble in water. This change is considered as the consequence of the absorption of the oxygen of the atmosphere, for which the extractive principle has a strong affinity. But if the solution be left to itself, exposed to the atmosphere, the extract is totally destroyed in consequence of a kind of putrefaction which speedily commences.

* See his *Physical Chemistry*, ii. 65. See also Crell's *Annals*, 1798, ii. 483.

† *Ann. de Chim.* xliii. 19

5. When oxymuriatic acid is poured into a solution containing extractive, a very copious dark yellow precipitate is thrown down, and the liquid retains but a light lemon colour. These flakes are the oxygenized *extractive*. It is now insoluble in water; but hot alcohol still dissolves it. Chap. I.

6. The extractive principle unites with alumina, and forms with it an insoluble compound. Accordingly, if sulphate or muriate of alumina be mixed with a solution of extractive, a flaky insoluble precipitate appears, at least when the liquid is boiled; but if an excess of acid be present, the precipitate does not always appear.

7. It is precipitated from water by concentrated sulphuric acid, muriatic acid, and probably by several other acids. When the experiment is made with sulphuric acid, the fumes of vinegar generally become sensible.

8. Alkalies readily unite with extractive, and form compounds which are insoluble in water.

9. The greater number of metallic oxides form insoluble compounds with extractive. Hence many of them, when thrown into its solution, are capable of separating it from water. Hence also the metallic salts mostly precipitate extractive. Muriate of tin possesses this property in an eminent degree. It throws down a brown powder perfectly insoluble, composed of the oxide of tin and vegetable matter.

10. If wool, cotton, or thread, be impregnated with alum, and then plunged into a solution of extractive, they are dyed of a fawn brown colour, and the liquid loses much of its extractive matter. This colour is permanent. The same effect is produced if muriate of tin be employed instead of alum. This effect is still more

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complete if the cloth be soaked in oxymuriatic acid, and then dipt into the infusion of extractive. Hence we see that the extractive matter requires no other mordant than oxygen to fix it on cloth.

11. When distilled, extractive yields an acid liquid impregnated with ammonia *.

Properties of extracts.

It cannot be doubted that there are many different species of extractive matter; though the difficulty of obtaining each separately has prevented chemists from ascertaining its nature with precision. Extracts are usually obtained by treating the vegetable substance from which they are to be procured with water, and then evaporating the watery solution slowly to dryness. All extracts obtained by this method have an acid taste, and redden the infusion of litmus. They all yield a precipitate while liquid if they are mixed with ammonia. This precipitate is a compound of lime and insoluble extractive. Lime always causes them to exhale the odour of ammonia. It has been ascertained that the extractive principle is more abundant in plants that have grown to maturity than in young plants.

As the *extracts* of vegetables prepared by apothecaries for medical purposes, besides the extractive principle, always contain other bodies, frequently to the number of eight or more, and as the greater number of them are still but imperfectly examined, I shall satisfy myself at present with pointing out some of those vegetable substances which have been ascertained to contain extractive principle, and stating the constituents of such as have been analysed.

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* See Vauquelin.

Extractive of sap,

1. Extractive principle is not an uncommon ingredient in the sap of trees. Indeed Deyeux and Vauquelin found it in almost all those which they examined. It is usually thrown down when the sap is mixed with oxymuriatic acid, and it precipitates in brown flakes while the sap is evaporating on a sand bath.

Of bark,

2. It forms a constituent of the bark of all trees hitherto examined. This was evidently the case with all the barks which Mr Davy subjected to experiment; namely, those of oak, Leicester willow, Spanish chesnut, elm, common willow, and undoubtedly all barks which have an astringent taste; for tan and extractive seem scarcely ever to be found separate.

Of catechu,

3. The infusion of catechu contains an extractive principle, united chiefly to tan. It may be obtained in a state of purity by washing the catechu in powder repeatedly with water till the fluids obtained cease to precipitate gelatine. What remains is extractive. It is of a pale reddish brown colour and a slightly astringent taste, leaving in the mouth a sensation of sweetness. It has no smell. Its solution in water is at first yellow brown; but it acquires a tint of red when left exposed to the air. The solution in alcohol is of a dirty brown. It does not affect vegetable blues. Alkalies brighten its colour; but neither these bodies nor the alkaline earths precipitate it from water. Nitrate of alumina and muriate of tin render the solution slightly turbid. Nitrate of lead throws down a dense light-brown precipitate. It renders oxysulphate of iron green, and throws down a green precipitate, becoming black by exposure to the air. Linen, when boiled in the solution, extracts almost the whole of the extractive, and acquires a light red brown colour. When this extrac-

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tive is exposed to heat, it softens, and its colour becomes darker, but it does not melt. When distilled, it yields carbonic acid and carbureted hydrogen gas, weak acetic acid, and a little unaltered extractive. A porous charcoal remains *.

Of senna,

4. The infusion of senna contains a matter of a very peculiar nature, but which may be considered as a species of *extractive*. The senna of commerce consists of the dried leaves of the *cassia senna*, a shrub-like annual cultivated in Egypt. Water, at the ordinary temperature of the atmosphere, dissolves nearly one-half of the substance of these leaves. The infusion obtained has a brown colour, a bitter taste, and a peculiar aromatic odour. It contains a considerable proportion of carbonate of lime, sulphate of potash, and carbonate of magnesia, besides a little silica; but the most curious of its constituents is the extractive. When common air is made to pass for some hours through the infusion, a yellow coloured precipitate appears: the same substance is thrown down immediately by muriatic acid and oxymuriatic acid. It appears also when a current of oxygen gas is made to traverse the infusion. This substance is the extractive altered by its combination with oxygen. It has a slight bitter taste. It is no longer soluble in water. Alcohol dissolves it, but lets it fall when diluted. The alkalies dissolve it, and form a deep brown solution. On burning coals it emits a thick smoke, exhales an aromatic odour, and leaves a spongy charcoal. These properties indicate a very decided approach to the resinous state †.

* Davy on *Astringent Vegetables*, p. 25.

† Bouillon La Grange, *Ann. de Chim.* xxiv. 4.

Chap. I. Of quinquina.

5. The infusion of Peruvian bark likewise yields an extractive matter of a peculiar nature, which assumes a fine red colour when united to oxygen; and, like the extractive of senna, acquires nearly the properties of a resin. It was obtained by Fourcroy from the quinquina of St Domingo. Water, boiled on it till it refused to dissolve any thing more, was slowly evaporated, and the extract obtained was dissolved in alcohol. The alcohol, by evaporation, deposited the peculiar extractive. Its colour was brown, its taste bitter, insoluble in cold, but very soluble in hot water. It was soluble in alcohol. When dry it was black, brittle, and broke with a polished fracture. Lime-water precipitated it in the state of a red powder: oxymuriatic acid threw it down in the state of a fine red powder, neither soluble in water nor alcohol, but capable of uniting with alkalies. A stronger dose of oxymuriatic acid renders it yellow *.

Of saffron.

6. Saffron yields extractive matter in great abundance. This substance consists of the summits of the pistils of the *crocus sativus*. Almost the whole of it is soluble in water.

7. Steinacher has shown that distilled vinegar contains a quantity of extractive †.

The resemblance between extractive bodies and the colouring matter of plants is sufficiently striking. It is more than probable, that when this last set of bodies have been examined with more precision by chemists, they will be found to belong to the same class.

* Fourcroy, *Ann. de Chim.* viii. 120. † *Jour. de Phys.* lxv. 327.

SECT. XVIII.

OF THE NARCOTIC PRINCIPLE.

It has been long known that the milky juices which exude from certain plants, as the poppy, lettuce, &c. and the infusions of others, as of the leaves of the *digitalis purpurea*, have the property of exciting sleep, or, if taken in large enough dozes, of inducing a state resembling apoplexy, and terminating in death. How far these plants owe these properties to certain common principles which they possess is not known; though it is exceedingly probable that they do. But as a *peculiar substance* has been detected in *opium*, the most noted of the narcotic preparations, which possesses narcotic properties in perfection, we are warranted, till further experiments elucidate the subject, to consider it as the *narcotic principle*, or at least as one species of the substances belonging to this genus.

Opium.

Opium is obtained from the *papaver album*, or white poppy, a plant which is cultivated in great abundance in India and the East. The poppies are planted in a fertile soil and well watered. After the flowering is over, and the seed capsules have attained nearly their full size, a longitudinal incision is made in them about sun-set for three or four evenings in succession. From these incisions there flows a milky juice, which soon concretes, and is scraped off the plant and wrougl cakes. In this state it is brought to Europe.

Its properties.

Opium thus prepared is a tough brown sub has a peculiar smell, and a nauseous bitter acrid

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Constituents.

It becomes softer when held in the warm hand, and burns very readily and strongly. It is a very compound substance, containing sulphate of lime, sulphate of potash, an oil, a resinous body, an extractive matter, gluten, mucilage, &c. besides the peculiar narcotic principle, to which probably it owes its virtues as a narcotic. Almost all the medical chemists have published analyses of opium. To their labours indeed we are indebted for every thing concerning it at present known. Neumann, Hoffman, Trulles, Baumé, have distinguished themselves most; and more lately remarks have been published on it by Josse, Bucholz, Proust, and Dérosne. The dissertation of the last is peculiarly valuable. He first pointed out the nature and properties of the *narcotic principle* of opium. It had indeed been noticed by most of the older chemists, though they had formed erroneous opinions respecting its nature.

Separation of the narcotic principle.

When water is digested upon opium, a considerable portion of it is dissolved, the water taking up several of its constituents. When this solution is evaporated to the consistence of a syrup, a gritty precipitate begins to appear, which is considerably increased by diluting the liquid with water. It consists chiefly of three ingredients; namely, resin, oxygenized extractive, and the peculiar narcotic principle, which is crystallized. When alcohol is digested on this precipitate, the resin and narcotic substance are taken up, while the oxygenized extractive remains behind. The narcotic principle falls down in crystals as the solution cools, still however coloured with resin. But it may be obtained tolerably pure by repeated solutions and crystallizations *.

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* [illegible] *de Chim.* xlv. 263.

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Water is incapable of dissolving the whole of opium. What remains behind still contains a considerable portion of narcotic principle. When alcohol is digested on this residuum, it acquires a deep red colour; and deposites on cooling crystals of narcotic principle, coloured by resin, which may be purified by repeated crystallizations *. The narcotic principle obtained by either of these methods possesses the following properties.

Its properties.

1. Its colour is white. It crystallizes in rectangular prisms with rhomboidal bases. It has neither taste nor smell.

2. It is insoluble in cold water, soluble in about 400 parts of boiling water, but precipitates again as the solution cools. The solution in boiling water does not affect vegetable blues.

3. It is soluble in 24 parts of boiling alcohol and 100 parts of cold alcohol. When water is mixed with the solution, the narcotic principle precipitates in the state of a white powder.

4. Hot ether dissolves it, but lets it fall on cooling.

5. When heated in a spoon it melts like wax. When distilled it froths and emits white vapours, which condense into a yellow oil. Some water and carbonate of ammonia pass into the receiver; and at last carbonic acid gas, ammonia, and carbureted hydrogen gas, are disengaged. There remains a bulky coal, which yields traces of potash. The oil obtained by this process is viscid, and has a peculiar aromatic smell and an acrid taste.

6. It is very soluble in all acids. Alkalies throw it down from these solutions in the state of a white powder.

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* Derosne, *Ann. de Chim.* xlv. p. 271.

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7. Alkalies render it rather more soluble in water. When they are saturated with acids, the narcotic principle falls down in the state of a white powder, which is redissolved by adding an excess of acid.

8. Volatile oils, while hot, dissolve it; but, on cooling, they let it fall in an oleagenous state at first, but it gradually crystallizes.

9. When treated with nitric acid, it becomes red and dissolves; much oxalic acid is formed, and a bitter substance remains behind.

10. When potash is added to the aqueous solution of opium, the narcotic principle is thrown down; but it retains a portion of the potash.

11. Its solubility in water and alcohol, when immediately extracted from opium, seems to be owing to the presence of *resin* and *extractive matter*, both of which render it soluble.

12. It possesses the properties of opium in perfection. Dérosne tried it upon several dogs, and found it more powerful than opium. Its bad effects were counteracted by causing the animals to swallow vinegar. This substance is known to be of equal service in counteracting the effects of opium. Dérosne supposes that the efficacy of vinegar may be owing to the readiness with which it dissolves the narcotic principle *.

Many other substances beside opium possess narcotic virtue; but hitherto they have not been examined by chemists with much attention. The most remarkable are the following:

Narcotic plants.

1. The *lactuca virosa*, and the *sativa* or garden let-

* Derosne, *Ann. de Chim.* p. 274.

Book IV. tuce, and indeed all the lactucas, yield a milky juice, which, when inspissated, has very much the appearance of opium, and possesses the same properties. Indeed Dr Coxe of Philadelphia affirms, that as good opium may be obtained from the garden lettuce as from the poppy. The milky juice is obtained by incisions at the time when the lettuce is running to seed *. The resemblance between the inspissated juice of the *lactuca virosa* and opium is striking.

2. The leaves of the *atropa belladona*, or *deadly nightshade*, and indeed the whole plant, are remarkably narcotic; and when taken in too great doses produce blindness, convulsions, coma, and death.

3. The leaves of the *digitalis purpurea*, or *fox-glove*, are still more powerful if possible. They lower the pulse in a remarkable degree, and, like several other very poisonous narcotics, promote the discharge of urine.

4. Hyosyamus niger or hen-bane.

5. Conium maculatum or hemlock.

6. Datura stramonium.

7. Ledum palustre.

To these may perhaps be added the *prunus laurocerasus*, and the leaves of *nicotiana tabacum* or *tobacco*. The list indeed might be easily increased; almost all the plants belonging to the natural order of *luridæ* possessing narcotic properties: But as we are completely ignorant of the chemical properties of these plants, it is unnecessary to be more particular.

* *Phil. Mag.* ix. 135.

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SECT. XIX.

OF OILS.

There are two species of oils; namely, *fixed* and *volatile*; both of which are found abundantly in plants.

1. Fixed oil is only found in the seeds of plants, and is almost entirely confined to those which have two cotyledons; as linseed, almonds, beech root, poppy seed, rape seed, &c. Sometimes, though rarely, it is found in the pulp which surrounds the stone of certain fruits. This is the case with the olive, which yields the most abundant and most valuable species of fixed oil. The bicotyledinous seeds, besides oil, contain also a mucilaginous substance; and they have all the character of forming, when bruised in water, a milky liquid, known by the name of *emulsion*.

The following is a list of the plants which yield the fixed oils which usually occur in commerce *.

List of fixed oils.

1. Linum usitatissimum et perenne	Linseed oil
2. Corylus avellana	Nut oil
3. Juglans regia	Nut oil
4. Papaver somniferum..............	Poppy oil
5. Cannabis sativa..................	Hemp oil
6. Sesamum orientale................	Oil of Sesamum

* See Gren's *Handbuch*, ii. 166.

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7.	Olea Europea......................	Olive oi
8.	Amygdalus communis.............	Almond
9.	Guilandina Mohringa..............	Oil of b
10.	Cucurbita pepo et melapepo.......	Cucuml
11.	Fagus sylvatica......................	Beech o
12.	Sinapis nigra et arvensis..........	Oil of n
13.	Helianthus annuus et perennis...	Oil of su
14.	Brassica napus et campestris.....	Rape se
15.	Ricinus communis.................	Castor
16.	Nicotiana tabacum et rustica.....	Tobacc
17.	Prunus domestica...............	Plum k
18.	Vitis vinifera...................	Grape
19.	Theobroma cacao..............	Butter
20.	Laurus nobilis.................	Laurel
21.	Arachis hypogæa	Ground

2. Volatile oils are found in every part of pl cept the cotyledons of the seeds, where they n cur. The root, the stem, the leaves, the flov rind or pulp of the fruit of a variety of plants, a ed with volatile oils, from which they are extr expression or by distillation. The number of tl is so great that it baffles all description. Almo plant which is distinguished by a peculiar odo tains a volatile oil, to which it is indebted odour.

The following Table contains a pretty copio plants which yield volatile oils. The part of t from which it is extracted, and the English nam oil, are added in separate columns †.

* Nicholson's *Jour*. vi. 224.

† See Gren's *Handbuch*, ii. 204.

Plants.	Parts.	Oil of	Colour.
1. Artemisia absynthium	Leaves	Wormwood	Green
2. Acorus calamus	Root	Sweet flag	Yellow
3. Myrtus Pimenta	Fruit	Jamaica pep. §	Yellow
4. Anethum graveolens	Seeds	Dill	Yellow
5. Angelica archangelica	Root	Angelica	
6. Pimpinella anisum	Seeds	Anise	White
7. Illicium anisatum	Seeds	Stellat. anise	Brown
8. Artemisia vulgaris	Leaves	Mugwort	
9. Citrus aurantium	Rind of the fruit	Bergamotte	Yellow
10. Meloleuca leucodendra	Leaves	Cajeput	Green
11. Eugenia caryophyllata	Capsules	Cloves §	Yellow
12. Carum carvi	Seeds	Caraways	Yellow
13. Amomum cardamomum	Seeds	Card. seeds	Yellow
14. Carlina acaulis	Roots		White
15. Scandix chaerefolium	Leaves	Chervil	Sulph. yel.
16. Matricaria chamomilla	Petals	Chamomile	Blue
17. Laurus cinnamomum	Bark	Cinnamon §	Yellow
18. Citrus medica	Rind of the fruit	Lemons	Yellow
19. Cochlearia officinalis	Leaves	Scurvy grass	Yellow
20. Copaifera officinalis	Extract	Copaiba	White
21. Coriandrum sativum	Seeds	Coriand. seed	White
22. Crocus sativus	Pistils	Saffron §	Yellow
23. Piper cubeba	Seeds	Cubeb pep.	Yellow
24. Laurus culilaban	Bark	Culilaban	Brown yel.
25. Cuminum cyminum	Seeds	Cummi	Yellow
26. Inula helenium	Roots	Elecampane	White
27. Anethum fœniculum	Seeds	Fennel	White
28. Croton eleutheria	Bark	Cascarilla	Yellow
29. Maranta galanga	Roots	Galanga	Yellow
30. Hyssopus officinalis	Leaves	Hyssop	Yellow
31. Juniperus communis	Seeds	Juniper	Green
32. Lavendula spica	Flowers	Lavender	Yellow
33. Laurus nobilis	Berries	Laurel	Brownish
34. Prunus laurocerasus	Leaves	Lauroceras. §	
35. Levisticum ligusticum	Roots	Lovage	Yellow
36. Myristica moschata	Seeds *	Mace	Yellow

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List of volatile oils.

§ The oils marked § sink in water.

* They yield also a fixed oil.

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Plants.	Parts.	Oil of	Colour.
37. Origanum majorana	Leaves	Marjorum	Yellow
38. Pistacia lentiscus	Resin	Mastich	Yellow
39. Matricaria parthenium	Plant	Motherwort	Blue
40. Melissa officinalis	Leaves	Balm	White
41. Mentha crispa	Leaves		White
42. ——— piperitis	Leaves	Peppermint	Yellow
43. Achillea millefolium	Flowers	Millefoil	Blue and green
44. Citrus aurantium	Petals	Neroli	Orange
45. Origanum creticum	Flowers	Spanish hop	Brown
46. Apium petroselinum	Roots	Parsley	Yellow
47. Pinus sylvestris et abies	Wood & resin	Turpentine	Colourless
48. Piper nigrum	Seeds	Pepper	Yellow
49. Rosmarinus officinalis	Plant	Rosemary	Colourless
50. Mentha pulegium	Flowers	Pennyroyal	Yellow
51. Genista canariensis	Root	Rhodium	Yellow
52. Rosa centifolia	Petals	Roses	Colourless
53. Ruta graveolens	Leaves	Rue	Yellow
54. Juniperus sabina	Leaves	Savine	Yellow
55. Salvia officinalis	Leaves	Sage	Green
56. Santalum album	Wood	Santalum §	Yellow
57. Laurus sassafras	Root	Sassafras	Yellow
58. Satureia hortensis	Leaves	Satureia	Yellow
59. Thymus serpillum	Leaves and flower	Thyme	Yellow
60. Valeriana officinalis	Root	Valerian	Green
61. Kæmpferia rotunda	Root	Zedoary	Greenish blue
62. Amomum Zinziber	Root	Ginger	Yellow
63. Andropogon schænanthum		Sira	Brown

Several of the gum resins, as *myrrh* and *galbanum*, yield likewise an essential oil, and likewise the balsams, as *benzoin*, &c.

Chap. I.

SECT. XX.

OF WAX.

THE upper surface of the leaves of many trees is covered with a varnish, which may be separated and obtained in a state of purity by the following process:

How obtained from plants.

Digest the bruised leaves, first in water and then in alcohol, till every part of them which is soluble in these liquids be extracted. Then mix the residuum with six times its weight of a solution of pure ammonia, and, after sufficient maceration, decant off the solution, filter it, and drop into it, while it is incessantly stirred, diluted sulphuric acid, till more be added than is sufficient to saturate the alkali. The varnish precipitates in the form of a yellow powder. It should be carefully washed with water, and then melted over a gentle fire *.

Mr Tingry first discovered that this varnish possessed all the properties of *bees wax* †. Wax, then, is a vegetable product. Several plants contain wax in such abundance as to make it worth while to extract it from them. But let us, in the first place, consider the properties of bees wax, the most common and important species. This substance, as Huber has demonstrated, contrary to the generally received opinion, is prepared

* Hermbstadt, *Med. and Phys. Jour.* iii. 372.
† *Enc. Meth. Forets et Bois*, i. 100.

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by the bees from honey or sugar, the latter yielding the greatest proportion of it *.

Properties of bees wax.

1. Wax, when pure, is of a whitish colour; it is destitute of taste, and has scarcely any smell. Bees wax indeed has a pretty strong aromatic smell; but this seems chiefly owing to some substance with which it is mixed; for it disappears almost completely by exposing the wax, drawn out into thin ribands, for some time to the atmosphere. By this process, which is called *bleaching*, the yellow colour of the wax disappears, and it becomes very white. Bleached wax is not affected by the air †.

2. The specific gravity of unbleached wax varies from 0·9600 ‡ to 0·9650 §; that of white wax from 0·8203 to 0·9662 §.

3. Wax is insoluble in water; nor are its properties altered though kept under that liquid.

4. When heat is applied to wax it becomes soft; and at the temperature of 142°, if unbleached, or of 155° if bleached ||, it melts into a colourless transparent fluid, which concretes again, and resumes its former appearance as the temperature diminishes. If the heat be still farther increased, the wax boils and evaporates; and if a red heat be applied to the vapour, it takes fire and burns with a bright flame. It is this property which renders wax so useful for making candles.

Action of alcohol,

5. Wax is scarcely acted on by alcohol when cold, but boiling alcohol dissolves it. This was known to

* Nicholson's *Jour.* ix. 182.

† Sennebier, *Ann. de Chim.* xii. 60. and *Jour. de Phys.* xxxviii. 56.

‡ Bostock, Nicholson's *Jour.* iv. 130.

§ Fabroni, Crell's *Annals*, 1797, ii. 125.

|| Bostock, Nicholson's *Jour.* i. 71.

Neumann *, and has been lately verified by Dr Bostock †. Rather more than 20 parts of alcohol are necessary to dissolve one part of wax; and as the solution cools, the greater part of the wax precipitates, and the remainder is thrown down by water ‡. Chap. I.

6. Ether has but little action on wax while cold; but when assisted by heat, it takes up about $\frac{1}{16}$th of its weight of it, and lets the greatest part precipitate on cooling §.

7. Wax combines readily with fixed oils when assisted by heat, and forms with them a substance of greater or less consistency according to the quantity of oil. This composition, which is known by the name of *cerate*, is much employed by surgeons.

The volatile oils also dissolve it when heated. This is well known, at least, to be the case with oil of turpentine. A part of the wax precipitates usually as the solution cools, but of a much softer consistence than usual, and therefore containing oil.

8. The fixed alkalies combine with it, and form a compound which possesses all the properties of common soap. When boiled with a solution of fixed alkalies in water, the liquid becomes turbid, and after some time the soap separates and swims on the surface. It is precipitated from the alkali by acids in the state of flakes, which are the wax very little altered in its properties ‖. Punic wax, which the ancients employed in painting in encausto, is a soap composed of 20 parts of wax and Action of Alkalies,

* Neumann's *Chemistry*, p. 331.
† Nicholson's *Jour.* iv. 133.
‡ Id. Ibid.
§ Id. Ibid.
‖ Id. Ibid, p. 132.

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one of soda *. Its composition was ascertained by M Lorgna †.

When boiled with liquid ammonia, it forms a kin of soapy emulsion. As the mixture cools, the greate part of the compound rises to the surface in the sta of white flakes. This soap is scarcely soluble in wa ter ‡.

9. The acids have but little action on wax; eve oxymuriatic acid, which acts so violently on most bo dies, produces no other change on it than that of ren dering it white. This property which wax possesse of resisting the action of acids, renders it very usef as a lute to confine acids properly in vessels, or to pre vent them from injuring a common cork.

Composition.

10. Mr Lavoisier, by means of the apparatus whic he employed in the analysis of alcohol and oils, an which has been described in the First Part of this Wor contrived to burn wax in oxygen gas. The quanti of wax consumed was 21·9 grains. The oxygen ga employed in consuming that quantity amounted to 66·5 grains. Consequently the substances consumed amoun ed to 88·45 grains. After the combustion, there we found in the glass vessel 62·58 grains of carbonic aci and a quantity of water, which was supposed to amou to 25·87 grains. These were the only products.

Now 62·58 grains of carbonic acid gas contain 44·36 of oxygen and 18·02 of carbon; and 25·87 grains of water cont 21·99 of oxygen and 3·88 of hydrogen

66·55 21·90

Consequently 21·9 parts of wax are composed of 18·

* Pliny, lib. xxi. c. 14. † *Jour. de Phys.* Nov. 1785.
‡ Bostock, Nicholson's *Jour.* iv. 134.

of carbon and 3·88 of hydrogen. And 100 parts of wax are composed of 82·28 carbon Chap. I.

17·72 hydrogen

100·00 *

But this analysis can only be considered as an approximation to the truth; the quantity of water being only estimated, and that of the gas being liable to uncertainty. There can be no doubt, from the little action of acids on wax, that it contains oxygen as an ingredient. We must therefore consider it as a triple compound of carbon, hydrogen, and oxygen; but the proportions are unknown.

If wax be distilled with a heat greater than 212°, there comes over a little water, some acid, a very little fluid and odorous oil: the oil, as the distillation advances, becomes thicker and thicker, till at last it is of the consistency of butter, and for this reason has been called *butter of wax*. There remains in the retort a small quantity of coal, which is not easily reduced to ashes. When the butter of wax is repeatedly distilled, it becomes very fluid, and assumes the properties of volatile oil †.

11. Wax possesses all the essential properties of fixed oil. We must therefore consider it as a fixed oil rendered concrete. Now that species of fixed oils, distinguished by the epithet *fat*, have the property of becoming concrete, and assuming the appearance of wax, when exposed long to the air; in consequence, it is supposed, of the absorption of oxygen. Hence proba-

* Lavoisier, *Jour. de Phys.* xxxi. 59.
† Lemery, *Mem. Par.* 1708. p. 53.

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bly the difference between wax and fixed oils consists in the oxygen which it contains as a component part. The wax at its first formation was in all probability in the state of a fixed oil; but by the absorption of oxygen it gradually concreted into wax. Wax, then, may be considered as a fixed oil saturated with oxygen.

Varieties of wax.

12. It is natural to suppose, if this theory be just, that fixed oil will occur in plants in various states of hardness: and this accordingly is the case. Sometimes it is of the consistency of butter, and this is denominated a *butter*; thus we have the butter of *cacao*, the butter of *coco*, the butter of *galam*. Sometimes it is of a greater consistency, and then is denominated *tallow*; thus we have the tallow of the *croton*, extracted by boiling water from the fruit of the *croton sebifera*. When its consistency is as great as possible, it then takes the appellation of *wax*. Thus we have the *myrtle wax* of America, extracted from the seeds of the *myrica cerifera*, and the *pela* of the Chinese. The species of wax, then, which exist in the vegetable kingdom, may possibly be as numerous as the fixed oils. Let us take a view of some of the most remarkable.

Bees wax is the species whose properties have been described in the former part of this Section.

Myrtle wax.

13. The myrtle wax of North America is obtained from the *myrica cerifera*. We are indebted to Dr Bostock * and Mr Cadet † for a very exact account of its properties and extraction. The *myrica cerifera* is a shrub which grows abundantly in Louisiana and other parts of North America. It produces a berry about

* Nicholson's *Jour*. iv. 130. † *Ann. de Chim*. xliv. 160.

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the size of a pepper corn. A very fertile shrub yields nearly seven pounds. The berries are picked off, thrown into a kettle, and covered with water to the depth of about half a foot. The kettle is then boiled, and the berries stirred and squeezed against the sides of the vessel. The wax which they contain is melted out and swims on the surface. It is skimmed off, passed through a cloth, dried, melted again, and cast into cakes. From the observations of Cadet, we learn that the wax forms the outer covering of the berries. The wax thus obtained is of a pale green colour. Its specific gravity is 1·0150. It melts at the temperature of 109°: when strongly heated it burns with a white flame, produces little smoke, and during the combustion emits an agreeable aromatic odour. Water does not act upon it. Alcohol, when hot, dissolves $\frac{1}{20}$th of its weight, but lets most of it fall again on cooling. Hot ether dissolves about $\frac{1}{4}$th of its weight; and when slowly cooled, deposites it in crystalline plates, like spermaceti. The ether acquires a green colour, but the wax becomes nearly white. Oil of turpentine, when assisted by heat, dissolves it sparingly. Alkalies act upon it nearly as on bees wax. The same remark applies to acids. Sulphuric acid, when assisted by heat, dissolves about $\frac{1}{12}$th of its weight, and is converted into a thick dark brown mass *. Mr Hatchett has lately detected a substance precisely similar to myrtle wax in *lac* †. It probably exists in many vegetables.

11. The Chinese extract a wax from various vegetables, which they manufacture into candles, and of

* Bostock, Nicholson's *Jour.* iv .130.

† Analytical Experiments on Lac, *Phil. Trans.* 1804.

Book IV. which they form many of the delicate ornaments which are brought to Europe *.

15. Wax has been detected by Proust in the green fecula of many plants; the cabbage for instance. He thinks that it forms a constituent of the pollen of all flowers, and that the bees collect it along with the gluten of the pollen, which, according to him, serves them for food †. But there is undoubted evidence that wax is actually formed by bees. The observations of Mr John Hunter led him to conclude that it comes from under the scaly rings which cover their hinder parts.

Proust has also detected wax covering the rind of resins, plums, oranges, and other similar fruits ‡. In short, it seems to be one of the most abundant of vegetable principles.

SECT. XXI.

OF CAMPHOR.

History. The substance called *camphor*, though unknown to the Greeks and Romans, seems to have been long known in the East. When it was first brought to Europe does not appear, though it seems to have been introduced by the Arabians. Ætius is the first person

* See *Phil. Trans.* 1753, p. 253; in which Father d'Incarville gives some account of the tallow tree, and mode of extracting the tallow or wax.

† *Jour. de Phys.* lvi. 87. and 111.

‡ Ibid.

who takes notice of it. It is mentioned in the writings of Paracelsus, in such a manner as to lead to the supposition that it was in common use in his time. Chemists sometimes arranged it among resins, sometimes among volatile oils *, till Neumann published his dissertation on it in 1725 †. He there examined its properties in detail, and demonstrated that they differed from those of every other substance; and concluded in consequence, that camphor must be considered as a peculiar vegetable principle. To Neumann, then, we are indebted for the first correct experiments on the properties of camphor.

How procured.

It comes to Europe chiefly from Japan. It is obtained from the *laurus camphora*, a tree common in the East, by distilling the wood along with water in large iron pots, on which are fitted earthen heads stuffed with straw. The camphor sublimes, and concretes upon the straw in the form of a grey powder ‡. It is afterwards refined in Holland by a second sublimation. The vessels are of glass, and somewhat of the shape of a turnip, with a small mouth above loosely covered with paper. According to Ferber, about $\frac{1}{4}$th of pounded chalk is mixed with the crude camphor §; but others assure us that there is no addition whatever employed. According to Lewis, nothing more is necessary than a proper regulation of the fire ||; and Professor Robison, who witnessed the process as well as Neumann, informs us, that the camphor in the subliming vessel is in a liquid state, which it could scarcely be if quick-

* Hoffmann, *Observ. Phys. Chym. Select.* p. 44.

† *Phil. Trans.* xxxiii. 321.

‡ Neumann's *Chem.* p. 319.

§ Gren's *Handbuch*, ii. 219.

|| Neumann, Ibid.

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lime were employed, at least in any considerable quantity *.

Properties.

1. Camphor thus refined is a white brittle substance, having a peculiar aromatic odour, and a strong hot acrid taste. Its specific gravity is 0·9887 †.

It is not altered by atmospheric air; but it is so volatile, that if it be exposed during warm weather in an open vessel, it evaporates completely. When sublimed in close vessels it crystallizes in hexagonal plates or pyramids ‡.

2. It is insoluble in water; but it communicates to that liquid a certain portion of its peculiar odour §.

Action of alcohol.

3. It dissolves readily in alcohol, and is precipitated again by water. According to Neumann, well rectified alcohol dissolves three-fourths of its weight of camphor. By distillation the alcohol passes over first, and leaves the camphor. This property affords an easy method of purifying camphor. Dissolve the camphor in alcohol, distil off the spirit, and melt the camphor into a cake in a glass vessel ‖. If the alcoholic solution of camphor be diluted with water as much as possible, without causing the camphor to pre-

* Black's *Lectures*, ii. 351.

† According to Brisson. Dr Shaw states it at 0·996 (Shaw's *Boyle*, ii. 346.); and this has been copied into most of the recent chemical books. Probably it varies in its density considerably.

‡ Romieu.

§ From the experiments of Cadet it appears, that a French pint of water dissolves about 16 grains of camphor, and that the camphor may be precipitated by pure potash. *Ann. de Chim.* lxii. 132.

‖ This process, proposed by Lewis (Neumann's *Chem.* p. 320.), is surely preferable to that of Trommsdorf, who precipitates the camphor by water from the alcohol, and then melts it into a cake. See Gren's *Handbuch*, ii. 220.

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cipitate, small crystals of camphor resembling feathers gradually form *.

Oils,

4. Camphor is soluble also in oils, both fixed and volatile. If the solution be made by means of heat, as it cools part of the camphor precipitates, and assumes the form of plumose or feather-like crystals †.

Alkalies,

5. Camphor is not acted on by alkalies, either pure or in the state of carbonates. Pure alkalies indeed seem to dissolve a little camphor ; but the quantity is too small to be perceptible by any other quality than its odour ‡. Neither is it acted on by any of the neutral salts which have hitherto been tried.

Acids.

6. Acids dissolve camphor without effervescence, and in general it may be precipitated unaltered from the recent solution.

Sulphuric acid.

To Mr Hatchett we are indebted for an accurate investigation of the action of sulphuric acid on camphor. Upon a hundred grains of powdered camphor he poured an ounce of sulphuric acid. The camphor immediately became yellow, and gradually dissolved while the acid changed, first to brownish red, and afterwards to brown. In about an hour the liquid became blackish brown, and began to emit abundance of sulphurous acid gas. In four hours the whole appeared like a thick black liquid, and no other smell except that of sulphurous acid could be distinguished in it. As during two days no farther alteration took place, the alembic containing the solution was put upon a sand bath moderately warm, by which means an additional

* Romieu, *Mem. Par.* 1756, p. 41. † Romieu, Ibid.

‡ Bouillon la Grange. *Ann. de Chim.* xxiii. 154.

Book IV. quantity of sulphurous acid gas was driven off. After two days the liquid was slowly mixed with six ounces of water. It became reddish brown, a considerable coagulum of the same colour subsided, the sulphurous acid smell became imperceptible, and was succeeded by a smell similar to that of a mixture of the oils of lavender and peppermint. The whole was now slowly distilled. The water which came over had the same smell as the original liquid, and there floated over it a little yellowish oil. A blackish brown mass remained behind, not acted on by water; but alcohol extracted a resinous substance, and acquired a blackish brown colour. What remained was charcoal. Thus, by the action of sulphuric acid, the camphor was decomposed and converted into oil, blackish brown resin, and charcoal. The proportion of each was as follows;

Yellow oil	3 grains
Charcoal	53
Resinous substance	49
	105

Making an increase of five grains, either from water which was retained by the resinous-like substance, or from oxygen with which it had combined.

The resinous-like substance, thus obtained, was in reality a species of artificial tannin. It was very brittle, had the odour of caromel, and an astringent taste. It dissolved in cold water, and the solution precipitated iron, lead, tin, and lime, dark brown. It precipitated gold in the metallic state, threw down isinglass in the state of a blackish insoluble substance, and had the property of converting skin into leather. A small

quantity of nitric acid converted it into the artificial tannin obtained from charcoal by nitric acid *.

Nitric acid. Nitric acid dissolves camphor readily, and in great abundance. The solution separates into two portions; that which contains the camphor, and most of the acid, floats upon the top of the other in the form of a very pale yellow oil. This solution is known by the name of *oil of camphor*. Water and several metals precipitate the camphor unaltered †. Alcohol combines with the oil of camphor. When this solution of camphor in nitric acid is long kept, a portion of the camphor separates in crystals, and swims on the surface, and a small portion is converted into camphoric acid ‡.

Other acids. Muriatic, sulphurous, and fluoric acids, in the state of gas, dissolve camphor. When water is added, the camphor appears unaltered in flakes, which swim on the surface of the water §. It is dissolved also by water impregnated with carbonic acid gas ||, by acetic acid ¶, and probably by all acids.

Action of heat. 7. When heat is applied to camphor it is volatilized. If the heat be sudden and strong, the camphor melts before it evaporates; and it melts, according to Venturi, at the temperature of 300°; according to Romieu, at 421° **. It catches fire very readily, and

* Hatchett's Additional Experiments on Artificial Tannin, *Phil. Trans.* 1805.

† Neumann's *Chemistry*, p. 321.

‡ Planche found these changes in a vial of oil of camphor, which had been kept unopened for 14 years. *Ann. de Chim.* xliii. 346.

§ Fourcroy.

|| *Jour. de Phys.* lii. 67.

¶ *Phil. Mag.* xv. 156. Aromatic vinegar consists chiefly of this compound.

** *Mem. Par.* 1756, p. 444.

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emits a great deal of flame as it burns, but it leaves no residuum. It is so inflammable that it continues to burn even on the surface of water. When camphor is set on fire in a large glass globe filled with oxygen gas, and containing a little water, it burns with a very bright flame, and produces a great deal of heat. The inner surface of the glass is soon covered with a black powder, which has all the properties of charcoal; a quantity of carbonic acid gas is evolved; the water in the globe acquires a strong smell, and is impregnated with carbonic acid and camphoric acid *.

If two parts of alumina and one of camphor be formed into a paste with water, and distilled in a glass retort, there comes over into the receiver (which should contain a little water, and communicate with a pneumatic apparatus) a volatile oil of a golden yellow colour, a little camphoric acid, which dissolves in the water, and a quantity of carbonic acid gas and carbureted hydrogen gas, which may be collected by means of a pneumatic apparatus. There remains in the retort a substance of a deep black colour, composed of alumina and charcoal. By this process, from 122·284 parts of camphor, Mr Bouillon la Grange, to whom we are indebted for the whole of the analysis of camphor, obtained 45·856 parts of volatile oil and 30·571 parts of charcoal. The proportion of the other products was not ascertained †.

From this analysis, Mr Bouillon la Grange concludes that camphor is composed of volatile oil and charcoal or carbon combined together. We learn from his ex-

* Bouillon la Grange, *Ann. de Chim.* xxiii. 168. † Ibid. p. 157

periments, that the ultimate ingredients of camphor are carbon and hydrogen; and that the proportion of carbon is much greater than in oils.

Species of camphor:

8. There are several species of camphor which have been examined by chemists, and which differ considerably from each other in their properties. The most remarkable are *common camphor*, the *camphor of volatile oils*, and the *camphor* obtained by treating *oil of turpentine* with *muriatic acid*.

1. Common camphor;

9. Common camphor, obtained by distillation from the *laurus camphora*, is the substance which has been described in the preceding part of this Section. In Borneo and Sumatra camphor is procured from the *laurus sumatrensis*; but as none of this camphor is brought to Europe, we do not know how far it agrees with common camphor in its properties. The *laurus cinnamomum* likewise yields camphor.

2. Camphor from oils;

10. The second species of camphor seems to exist in a great variety of plants, and is held in solution by the volatile oils extracted from them. Neumann obtained it from oils of thyme, marjoram, cardomum *; Hermann, from oils extracted from various species of mint †. Cartheuser obtained it from the roots of the *maranta galanga*, *kæmpferia rotunda*, *amomum zinziber*, *laurus cassia* ‡, and rendered it probable that it is contained in almost all the labiated plants. It has been supposed to exist in these plants combined with volatile oil. Proust has shown how it may be extracted,

* *Phil. Trans.* 1725, p. 321.

† Junker's *Conspectus Chemiæ*, ii. 100.

‡ *De Genericis Quibusdam Plantarum Princip.* 1734; as quoted by Gren, *Handbuch*, ii. 221.

Book IV. in considerable quantity, from many volatile oils *. All that is necessary, is to expose the oil to the open air at a temperature between 22° and 54°; the oil gradually evaporates, and the camphor crystallizes. By this process he obtained from the oil of rosemary $\frac{1}{16}$th of its weight of camphor, from that of sweet marjoram $\frac{1}{16}$th, from oil of sage $\frac{1}{8}$th, and from oil of lavender more than $\frac{1}{4}$th. By distilling the oil in a water-bath, some degrees under the boiling point, till one-third of of the oil comes over, part of the camphor is found crystallized in the still-vessel. This being removed, and the oil again distilled as before, more camphor crystallizes. By three such processes the whole of the camphor is obtained from the oil. The camphor is then purified by mixing it with a little dry lime, and subliming it.

From the observations of Mr John Brown, there is reason to believe that the camphor from oil of thyme differs from common camphor in several respects. It does not appear to form a liquid solution either with nitric or sulphuric acid; nor is it precipitated from nitric acid in powder like common camphor, but in a glutinous mass †.

3. Artificial camphor.

11. The artificial camphor yielded by oil of turpentine, when saturated with muriatic acid gas, was discovered by Mr Kind, apothecary in Eutin, while employed in making a medicine called the *liquor arthriticus Pottii*. He put a quantity of oil of turpentine into a Woulfe's bottle, and caused a current of muriatic acid gas,

How procured.

* *Ann. de Chim.* iv. 179.

† *Phil. Trans.* 1725, xxxiii. 361.

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separated from common salt by sulphuric acid, to pass through it. The salt used was of the same weight with the oil of turpentine. At first the oil became yellow, then brown, and at last became almost solid, from the formation of a great number of crystals in it, which possessed the properties of camphor *. This curious experiment was repeated by Trommsdorf with a similar result. He examined the camphoric crystals obtained, and found them in most respects to agree with common camphor, though in some they differed †. The society of apothecaries at Paris, on being informed of these particulars, appointed Messrs Cluzel, Chomet, and Boullay, to examine the subject. The result of their labours has been given to the world by Boullay ‡. They ascertained the proportion of camphor yielded by oil of turpentine, the best dose of muriatic acid gas, examined the properties of the camphoric production, and endeavoured to explain the way in which it had been formed. The experiment of Kind was repeated by Hagen in 1804 §; and more lately, a set of experiments on the same subject was made by Gehlen, Schuster, and Pesth, chiefly in order to elucidate the theory of the process ‖. Thenard has repeated them with the same object ¶.

The proportion of muriatic gas found to answer best, is what can be separated by sulphuric acid and heat from a quantity of common salt equal in weight to the oil of turpentine employed. The camphor produced

* Trommsdorf's *Jour. der Pharmacie*, xi. 132; as quoted in Gehlen's Jour. vi. 459.

† Ibid.

‡ *Ann. de Chim.* li. 270.

§ Gehlen's *Jour*. ii. 237.

‖ Ibid. vi. 470.

¶ *Mem. d'Arcueil*, ii. 29.

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amounts nearly to one-half of the oil of turpentine. The French apothecaries put into a Woulfe's bottle four pounds of oil of turpentine, and into a tubulated retort four pounds of common salt, and two pounds of sulphuric acid, and drove off the muriatic acid gas by means of heat. It was totally absorbed by the oil, the bulk of which was augmented by $\frac{1}{10}$th, while it became at the same time very hot. Its colour became brown; it retained its transparency; and drops of oil gradually formed at the bottom of it. In 24 hours it deposited regular crystals; which, being separated from the brown liquid with which they were mixed, and dried on blotting paper, weighed 24 ounces. The liquor being left for some days in a cellar, deposited four ounces more of the same crystals; and by exposure to an artificial cold of about 14°, two ounces more were obtained, making a total of 30 ounces, or $1\frac{7}{8}$ lb. from the four pounds of oil of turpentine. No additional crystals were obtained by increasing the quantity of gas; but the French chemists did not find that the produce of camphor was diminished by this augmentation, as had been concluded by Trommsdorf from his trials.

Properties.

The camphor thus procured was very white; it had a peculiar odour, in which that of the oil of turpentine could be distinguished. When washed with water, it became beautifully white, and gave no longer signs of containing an acid, but still had the smell of oil of turpentine. Water containing some carbonate of potash deprived it of part of this odour, but not the whole. When mixed with its own weight of charcoal powder, wood-ashes, quicklime, or porcelain clay, and sublimed, it was obtained in a state of purity.

Its smell when pure resembles that of common cam-

phor, but is not so strong. Its taste also resembles that of camphor. It swims on water, to which it communicates its taste, and burns upon its surface. It dissolves completely in alcohol, and is precipitated by water. Nitric acid, of the specific gravity 1·261, had no action on it, though it readily dissolves common camphor; but concentrated nitric acid dissolves it with the disengagement of nitrous gas; and water does not precipitate it from its solution as it does common camphor. Acetic acid does not dissolve it. When heated it sublimes without decomposition; and when set on fire burns like camphor.

Action of muriatic acid gas on oil of turpentine.

Such are the properties of this artificial camphor, as far as they have been investigated. We see from them that it resembles common camphor, except as far as regards the action of acids. In the experiment of Thenard, the residual liquid was not brown but colourless. He ascribes the brown colour of it, in preceding experiments, to the oil of turpentine used containing some resin mixed with it, whereas his had been purified by distilling it. According to him the oil of turpentine is not decomposed by this process. The residual liquid he thinks may be owing to the presence of some foreign oil in oil of turpentine. When this residual liquid is exposed to the air for some days it loses its acid properties, though it still contains abundance of acid. But the acid is neutrallized by the oil.

Gehlen ascertained that neither fluoric acid gas, sulphurous acid gas, nor ammoniacal gas, produce any such decomposition in oil of turpentine. Neither is any such change produced by the action of oxymuriatic acid

Book IV. gas *; but when oil of turpentine is distilled slowly at a heat of 122°, a number of crystals of camphor sublime from it †. No other oils tried yielded camphor when impregnated with muriatic acid gas ‡.

12. Camphor is much used in medicine. It is a powerful stimulant; it is considered as peculiarly efficacious in diseases of the urinary organs; it is often serviceable in mania, and procures sleep when every other medicine fails.

SECT. XXII.

OF BIRD-LIME.

Discovery. The vegetable principle to which I give the name of *bird-lime*, was first examined by Vauquelin, who found it possessed of properties different from every other. It was found collected on the epidermis of a plant brought to Europe by Michaud, and called *robinia viscosa* by Cels; constituting a viscid substance, which made the fingers adhere to the young twigs §. From the late analysis of *bird-lime* by Bouillon la Grange, it is obvious that it owes its peculiar properties to the presence of an analogous substance, which indeed constitutes the essen-

* Boullay, *Ann. de Chim.* li. 283.
† Boullay, Ibid.
‡ Ibid.
§ *Ann. de Chim.* xxviii. 223.

tial part of that composition *. Hence the reason why I have given the name of *bird-lime* to the principle itself. Chap. I.

1. Natural bird-lime (or that which exudes spontaneously from plants) possesses the following properties: 1. Natural bird-lime.

Its colour is green; it has no sensible taste or smell; is extremely adhesive; softens by the heat of the fingers, and sticks to them with great obstinacy. When heated it melts, swells up, and burns with a considerable flame, leaving a bulky charcoal behind it. It does not dissolve in water; alcohol has but little action on it, especially when cold. By the assistance of heat it dissolves a portion of it; but on cooling, allows the greatest part to precipitate again. When exposed to the air it continues glutinous, never becoming hard and brittle like the resins.

It combines readily with oils. Ether is its true solvent, dissolving it readily without the assistance of heat. The solution is of a deep green colour. The alkalies do not combine with it; the effect of the acids was not tried †. These properties are sufficient to distinguish bird-lime from every other vegetable principle.

It is not unlikely that the viscid substance which covers the stem of the *lychnis viscaria*, *saxifraga tridactylites*, and a few other plants common in this country, consists of this vegetable principle. It has not hitherto, as far as I know, been examined by any chemist.

2. Artificial bird-lime is prepared from different 2. Artificial bird-lime.

* Nicholson's *Jour*. xiii. 144.

† Vauquelin, *Ann. de Chim.* xxviii. 224.

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substances in different countries. The berries of t misletoe are said to have been formerly employed. Th were pounded, boiled in water, and the hot wa poured off. At present bird-lime is usually prepar from the middle bark of the holly. The process fo lowed in England, as described by Geoffroy, is as fo lows: The bark is boiled in water seven or eight ho till it becomes soft. It is then laid in quantities in t earth, covered with stones, and left to ferment or r for a fortnight or three weeks. By this fermentatio it changes to a mucilaginous consistency. It is th taken from the pits, pounded in mortars to a paste, a well washed with river water. Bouillon la Grange i forms us, that at Nogent le Rotrou bird-lime is ma by cutting the middle bark of the holly into small piec fermenting them in a cool place for a fortnight, a then boiling them in water, which is afterwards evap rated. At Commerci various other plants are used *

Bouillon la Grange made bird-lime for the purpo of analysis by the following process. He bruised sufficient quantity of the middle bark of the holl boiled it in water for four or five hours, and then d posited it in pits placed in earthen pans, where it co tinued, being moistened occasionally with water ti it became viscous. Lastly, it was freed from all h terogeneous substances by washing it with pure wate Thus prepared, it resembled the bird-lime of Com merci very exactly †.

Properties.

Its colour is greenish, its flavour sour, and its co sistence gluey, stringy, and tenacious. Its smell is s

* Nicholson's *Jour.* xiii. 145.

† Bouillon la Grange, Nicholson's *Jour.* ibid.

milar to that of linseed oil. When spread on a glass plate and exposed to the air and light it dries, becomes brown, loses its viscidity, and may be reduced to powder; but when water is added to it, the glutinous property returns. It reddens vegetable blues.

When gently heated it melts and swells, and emits an odour like that of animal oils. When heated on red hot coals, it burns with a lively flame, and gives out a great deal of smoke, leaving a white ash, composed of carbonate of lime, alumina, iron, sulphate, and muriate of potash.

Water has little action on bird-lime. When boiled in water the bird-lime becomes more liquid, but recovers its original properties when the water cools. The water, by this treatment, acquires the property of reddening vegetable blues, and when evaporated leaves a mucilaginous substance, which may be likewise separated by alcohol.

A concentrated solution of potash forms with bird-lime a whitish magma, which becomes brown by evaporation, while ammonia separates. The compound thus formed is less viscid than bird-lime, and in smell and taste resembles soap. In alcohol and water it dissolves almost completely, and possesses properties similar to those of soap.

Weak acids soften bird-lime and partly dissolve it; strong acids act with more violence. Sulphuric acid renders it black; and when lime is added to the solution, acetic acid and ammonia separate. Nitric acid cold has little effect; but when assisted by heat it dissolves the bird-lime; and the solution, when evaporated, leaves behind it a hard brittle mass. By treating this mass with nitric acid, a new solution may be ob-

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tained, which by evaporation yields malic and oxalic acids, and a yellow matter which possessed several of the properties of wax. Cold muriatic acid does not act on bird-lime; hot muriatic acid renders it black.

Bird-lime, when treated with oxymuriatic acid, became white, and is divided into hard compact masses, having unaltered bird-lime in their centre. This whit substance may be pulverised; it is insoluble in water does not melt when heated; and when treated with nitric acid, it neither becomes yellow, nor does it yiel resin.

Acetic acid softens bird-lime, and dissolves a certain portion of it. The liquid acquires a yellow colour. Its taste is insipid. When carbonate of potash is dropt into this solution, no precipitate falls. By evaporation it yields a resinous-like substance.

Some of the metallic oxides are reduced when heated with bird-lime. Litharge combines with it, and form a kind of plaster.

Alcohol of the specific gravity 0·817 dissolves bird lime at a boiling heat. On cooling it lets fall a yellow matter similar to wax. The filtered liquid is bitter nauseous, and acid. Water precipitates a substance si milar to resin.

Sulphuric ether dissolves bird-lime readily, and i great abundance. The solution is greenish. Whe mixed with water, an oily substance separates, whic has some resemblance to linseed oil. When evaporate a greasy substance is obtained, having a yellow colou and the softness of wax. Oil of turpentine dissolve bird-lime readily.

Such are the properties of artificial bird-lime, as f

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as they have been investigated by Bouillon La Grange*. It is obvious that it contained acetic acid, mucilage, and several alkaline and earthy bodies, which must be considered as foreign substances. When these are removed, the close analogy between artificial and natural bird-lime is sufficiently obvious.

SECT. XXIII.

OF RESINS.

It is at present the opinion of chemists, that *resins* stand in the same relation to the *volatile* oils that *wax* does to the *fixed*. Wax is considered as a fixed oil saturated with oxygen; resins, as volatile oils saturated with the same principle.

The resins are very numerous; and on account of the various purposes to which they are applied, and the peculiarity of their properties, constitute one of the most important genera of vegetable substances. Till lately they have been very much overlooked by chemists, who satisfied themselves with picking up doubtful information from artists and manufacturers. Many erroneous opinions concerning them have of course been admitted into every system of chemistry. The subject has lately engaged the attention of Mr Hatchett, whose consummate skill and happy talent for observation pe-

* Nicholson's *Journal*, xiii. 146.

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culiarly fitted him for the task. To that gentleman I am indebted for some of the most important facts in this Section.

Origin.

Resins often exude spontaneously from trees; they often flow from artificial wounds, and not uncommonly are combined at first with volatile oil, from which they are separated by distillation. The reader can be at no loss to form a notion of what is meant by *resin*, when he is informed that common *rosin* furnishes a very perfect example of a resin, and that it is from this substance that the whole genus derived their name: for rosin is frequently denominated *resin*.

I. Resins may be distinguished by the following properties:

Properties.

1. They are solid substances, naturally brittle; have a certain degree of transparency, and a colour most commonly inclining to yellow. Their taste is more or less acrid, and not like that of volatile oils; but they have no smell unless they happen to contain some foreign body. They are all heavier than water. They are all non-conductors of electricity; and when excited by friction, their electricity is negative.

Specific gravity.

2. Their specific gravity varies considerably. The following Table exhibits a view of the specific gravity of such of the resins as have been hydrostatically examined *.

Elemi.........	1·0182
Anime.........	1·0284

* The specific gravities in the text were ascertained by Brisson. The older writers differ so much from each other, that there is reason to suspect that the substances tried were not always those to which we at present give the same names.

Copal	1·0452
Tacamahac	1·0463
Rosin	1·0727
Mastich	1·0742
Sandarich	1·0920
Lac	1·1390
Labdanum	1·1862

3. When exposed to heat they melt; and if the heat be increased they take fire, and burn with a strong yellow flame, emitting at the same time a vast quantity of smoke. Action of heat,

4. They are all insoluble in water whether cold or hot; but when they are melted along with water, or mixed with volatile oil, and then distilled with water, they seem to unite with a portion of that liquid; for they become opaque, and lose much of their brittleness. This at least is the case with common rosin. Water,

5. They are all, with a few exceptions, soluble in alcohol, especially when assisted by heat. The solution is usually transparent; and when the alcohol is evaporated, the resin is obtained unaltered in its properties. Alcohol, according to Tingry, never takes up more than one-third of its weight of resin. When the solution is mixed with water, it becomes milky, and the resin falls in the state of a white powder. They are soluble also in sulphuric ether. Alcohol and ether,

6. Several of them are soluble in fixed oils, especially in the drying oils. The greater number are soluble in the volatile oils; at least in oil of turpentine, the one commonly employed. Oils,

7. Mr Hatchett first examined the action of fixed alkalies on resins, and ascertained, contrary to the received opinion of chemists, that alkaline leys dissolve Alkalies,

Book IV. them with facility. He reduced a quantity of commo rosin to powder, and gradually added it to a boilin lixivium of carbonate of potash ; a perfect solution wa obtained of a clear yellow colour, which continued pe manent after long exposure to the air. The experi ment succeeded equally with carbonate of soda, and wit solutions of pure potash or soda. Every other resi tried was dissolved as well as *rosin*. Nothing can af ford a more striking proof than this, of the necessity c repeating the experiments of our predecessors befor we put implicit confidence in their assertions. M Hatchett's discovery must lead to very important con sequences. The well-known fact, that the soap-ma kers in this country constantly mix *rosin* with the soap ; that it owes its yellow colour, its odour, and it easy solubility in water to this addition, ought to hav led chemists to have suspected the solubility of resin in alkalies. No such consequence, however, was draw from this notorious fact.

These alkaline solutions of resins have the prope ties of soap, and may be employed as detergents. Whe mixed with an acid, the resin is separated in flake usually of a yellow colour, and not much altered in i nature.

Ammonia acts but imperfectly upon resins, and doe not form a complete solution of any of those bodies hi therto tried.

Acids. 8. It was the received opinion of chemists that acid do not act upon resins. This opinion seems to hav been founded on the known effects of nitric acid upo oils, and on the old theory derived from that action

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that resins are compounds of an oil and an acid *. Mr Hatchett first ascertained this opinion also to be erroneous, and showed that most of the acids dissolve resins with facility, producing different phenomena according to circumstances.

Sulphuric acid,

When sulphuric acid is poured upon any of the resins in powder, it dissolves them in a few minutes. At first the solution is transparent, of a yellowish brown colour, and of the consistency of a viscid oil, and the resin may be precipitated nearly unaltered by the addition of water. If the solution be placed on a sand bath, its colour becomes deeper, sulphurous acid gas is emitted, and it becomes very thick, and of an intense black †. If the solution, some time after it is completed, and before it has acquired the deep black colour, be edulcorated, and the residuum digested in alcohol, and the alcohol afterwards separated by distillation, the residue is in part soluble in cold water, and the portion dissolved possesses the properties of artificial tannin ‡. Thus it appears, that sulphuric acid dissolves resins, but gradually acts upon them after the solution is completed, converting them first into artificial tannin, and afterwards reducing them to charcoal: for the last black state of the solution is owing to the evolution of this substance. The charcoal thus formed is dense, and burns rather like mineral than vegetable coal. Its quantity also is very considerable. The following Table exhibits a view of the proportion of charcoal obtained by Mr Hatchett, by digesting different resins in sulphuric acid,

* See Hoffman, *Observ. Phys. Chym. Select.* p. 55.

† Hatchett on an Artificial Tanning Substance, *Phil. Trans.* 1805.

‡ Hatchett's Third Series of Experiments, Ibid. 1806.

Book IV. edulcorating the residue, and separating the tan means of alcohol and water *. The quantity employed was always 100 grains.

Charcoal evolved.

Copal	67 grains.
Mastich	66
Elemi	63
Tacamahac	62
Amber	56
Rosin	43

The quantity of charcoal formed by this pr very remarkable. The same substances, when in the usual way by exposure to a red heat i vessels, yield very little charcoal. The followi ble exhibits the quantity obtained by Mr Hatch 100 grains of several of them †:

Mastich	4·50 grains
Amber	3·50
Rosin	0·65

Nitric acid. Nitric acid likewise dissolves the resins with but not without changing their nature. Mr H was first led to examine the action of this acid or by observing that resins are thrown down b from their solutions in alkalies in the state of precipitate; but when nitric acid is added in exc whole of the precipitate is redissolved in a boili This remarkable fact, which did not hold wh phuric or muriatic acids were used, led him to t ther the resins were soluble in nitric acid. He

* Hatchett's Third Series of Experiments, *Phil. Trans.* 18
† Hatchett, Ibid.

nitric acid of the specific gravity 1·38, on powdered rosin in a tubulated retort; and by repeated distillation formed a complete solution of a brownish yellow colour. The solution took place much sooner in an open matrass than in close vessels. The solution continues permanent, though left exposed to the air. It becomes turbid when water is added; but when the mixture is boiled, the whole is redissolved. When Mr Hatchett collected the precipitate thrown down by water by filtration, he found that it still possessed several of the properties of resin. The resin is thrown down from nitric acid by potash, soda, and ammonia; but an excess of these alkalies redissolves the precipitate, and forms brownish orange-coloured liquids. When Mr Hatchett dissolved resin in boiling nitric acid, the solution was attended with a copious discharge of nitrous gas; and when the powdered resin was thrown into cold nitric acid, a considerable effervescence soon took place, and a porous mass was formed, commonly of a deep orange colour.

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When the digestion of nitric acid upon a resinous substance is continued long enough, and the quantity of acid is sufficient, the dissolved resin is completely changed; it is not precipitated by water; and by evaporation, a viscid substance of a deep yellow colour is obtained, equally soluble in water and alcohol, and seemingly intermediate between resin and extractive *. If the abstraction of nitric acid be repeated, this substance gradually assumes the properties of artificial tan-

Tannin formed.

* Hatchett on an Artificial Tanning Substance, *Phil. Trans.* 1805.

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nin*. Thus it appears that nitric acid gradually alters the nature of resin, producing a suite of changes which terminate in artificial tannin, upon which nitric acid has no action.

Acetic acid.

Muriatic acid and acetic acid dissolve resin slowly, and it may be precipitated again from them unaltered. Mr Hatchett, to whom we are indebted for the knowledge of all these solutions, recommends acetic acid as an excellent solvent of resins for vegetable analyses. He employed it himself with much address in his analysis of the different varieties of lac †.

Distillation.

9. When resins are subjected to destructive distillation, we obtain, according to Gren, carbureted hydrogen and carbonic acid gas, a very small portion of acidulous water, and much empyreumatic oil. The charcoal is light and brilliant, and contains no alkali ‡.

Supposed to be volatile oils united to oxygen.

10. When volatile oils are exposed for some time to the action of the atmosphere, they acquire consistency, and assume the properties of resins. During this change they absorb a quantity of oxygen from the air. Westrumb put 30 grains of oil of turpentine into 40 cubic inches of oxymuriatic acid gas. Heat was evolved; the oil gradually evaporated, and assumed the form of yellow resin §. Mr Proust observed, that when volatile oil is exposed to the air, it is partly converted into a resin, and partly into a crystallized acid; usually the benzoic or the camphoric. Hence we see that the oil is converted into two distinct substances. During this

* Hatchett's Additional Experiments on Artificial Tannin, *Phil. Trans.* 1805.

† *Phil. Trans.* 1804.

‡ *Handbuch*, ii. 140.

§ Crell's *Annals*, i. 1790.

change oxygen is absorbed; and Fourcroy has observed that a portion of water is also formed *. It is probable, from these facts, that resin is volatile oil deprived of a portion of its hydrogen, and combined with oxygen. The experiments of Mr Hatchett have added much to the plausibility of this theory. Chap. I.

11. Hermbstadt affirms, that to know whether any vegetable substance contains resin, we have only to pour some sulphuric ether upon it in powder, and expose the infusion to the light. If any resin be present, the ether will assume a brown colour.

II. Having now described the general properties of resinous bodies, it will be proper to take a more particular view of those of them which are of the most importance, that we may ascertain how far each possesses the general characters of resins, and by what peculiarities it is distinguished from the rest. The most distinguished of the resins are the following: List of resins.

1. *Rosin.*—This substance is obtained from different species of *fir*; as the *pinus abies, sylvestris, larix, balsamea.* It is well known that a resinous juice exudes from the *pinus sylvestris*, or common Scotch fir, which hardens into tears. The same exudation appears in the *pinus abies*, or spruce fir. These tears constitute the substance called *thus*, or common frankincense. When a portion of bark is stripped off these trees, a liquid juice flows out, which gradually hardens. This juice has obtained different names according to the plant from which it comes. The *pinus sylvestris* yields *common turpentine*; the *larix, Venice turpentine*; the *balsamea,* Rosin.

* Fourcroy, viii. 16.

Book IV. *balsam of Canada*, &c. All these juices, which ar commonly distinguished by the name of turpentine, ar considered as composed of two ingredients; namely oil of turpentine and resin. When the turpentine i distilled, the oil comes over, and the rosin remains be hind. When the distillation is continued to dryness the residuum is known by the name of common rosin, or colophonium; but when water is mixed with it while yet fluid, and incorporated by violent agitation, the mass is called *yellow rosin*. During winter the wounds made in the fir trees become encrusted with a white brittle substance called *barras* or *galipot*, consisting of rosin united to a small portion of oil. The yellow rosin made by melting and agitating this substance in water is preferred for most purposes; because it is more ductile, owing probably to its still containing some oil *. The properties of rosin are those which have been detailed in the former part of this Section Its uses are numerous and well known.

Mastich. 2. *Mastich.*—This resin is obtained from the *pistacia lentiscus*; a tree which grows in the Levant, particu larly in the island of Chios. When transverse incision are made into this tree, a fluid exudes, which soon con cretes into yellowish semitransparent brittle grains †. In this state it is sold under the name of mastich. I softens when kept in the mouth, but imparts very littl taste. This has induced surgeons to employ it to fi up the cavities of carious teeth, which it does tole rably well. When heated, it melts and exhales fragrant odour. Its taste is slight, but not unple

* Neumann's *Chemistry*, p. 286. † Ibid. p. 297.

sant. In Turkey great quantities of it are said still to be chewed for sweetening the breath, and strengthening the gums. It is to this use of the resin as a masticatory that it is supposed to owe its name *. Mastich does not dissolve completely in alcohol; a soft elastic substance separates during the solution. This substance, in Neumann's experiments, amounted to about $\frac{1}{12}$th of the mastich †; but in those made more lately by Mr Matthews, it was nearly a fifth ‡. The nature of this insoluble portion was first examined by Kind §, who found it possessed of all the properties of caoutchouc. These experiments have lately been repeated by Mr Matthews with a similar result ||. Mr Brande, however, has observed, that when this insoluble substance is dried it becomes brittle, in which respect it differs from caoutchouc. He has observed also, that by passing a current of oxymuriatic gas through the alcoholic solution of mastich, a tough elastic substance is thrown down, precisely similar to the original insoluble portion **. When mastich is distilled either with water or alcohol, nothing considerable comes over with these liquids; but Hoffmann ascertained, that if the resin be first mixed in a mortar with its own weight of carbonate of potash, and afterwards distilled with alco-

Contains caoutchouc.

* See Neumann's *Chemistry*, p. 298.

† Ibid.

‡ Nicholson's *Jour*. x. 247.

§ Crell's *Annals*, 1794, ii. 185.

|| Nicholson's *Jour*. x. 247.

** *Phil. Mag*. xxv. 111. From these experiments, together with those of Dr Wollaston on this substance, there can be little doubt that it is a peculiar vegetable principle. It may be characterized thus: Brittle, semitransparent, fusible like resins, insoluble in water and alcohol, soluble in ether.

Book IV. hol, the liquid comes over both with the smell and taste of mastich *. With the other agents it exhibits the phenomena described in the former part of this Section.

Sandarach. 3. *Sandarach.*—This resin is obtained from the *juniperus communis* or common juniper. It exudes spontaneously, and is usually in the state of small round tears of a brown colour, and semitransparent, not unlike mastich, but rather more transparent and brittle. When chewed it does not soften as mastich does, but crumbles to powder. Mr Matthews found it almost completely soluble in eight times its weight of alcohol. The residue was extraneous matter †. It does not dissolve in tallow or oil, as common resin does ‡. Mr Hatchett found it soluble in alkalies and acids with the same phenomena as common resin §.

Elemi. 4. *Elemi.*—This resin is obtained from the *amyris elemifera;* a tree which grows in Canada and Spanish America. Incisions are made in the bark during dry weather, and the resinous juice which exudes is left to harden in the sun. It comes to this country in long roundish cakes wrapped in flag leaves. It is of a pale yellow colour, semitransparent; at first softish, but it hardens by keeping. Its smell is at first strong and

* Hoffmann, *Observ. Phys. Chim. Select.* p. 68.

† Nicholson's *Jour.* x. 246.

‡ Ibid.

§ Giese, an apothecary of Augsburg, announced in Scherer's Journal for 1802, p. 536, that sandarach does not dissolve completely in alcohol; that the residue amounts to about one-fifth of the whole. This residue he considers as a peculiar substance. Mr Matthews proved, by a set of experiments, that the whole of this statement is inaccurate. I have no doubt that Giese employed mastich instead of sandarach, and that the insoluble substance detected was caoutchouc

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fragrant, but it gradually diminishes. Neuman found that alcohol dissolved $\frac{11}{12}$ths of this substance; the remainder consisted chiefly of impurities, and was partly taken up by water. Both water and alcohol, when distilled with it, come over strongly impregnated with its flavour. Along with the water there comes over a fragrant volatile oil, which amounts to about $\frac{1}{16}$th of the resin employed *.

Tacamahac.

5. *Tacamahac.*—This resin is obtained from the *fagara octandra*, and likewise, it is supposed, from the *populus balsamifera*. It comes from America in large oblong masses wrapt in flag leaves. It is of a light brown colour, very brittle, and easily melted when heated. When pure it has an aromatic smell between that of lavender and musk. When distilled along with water or alcohol, nothing comes over with these liquids. When pure it dissolves completely in alcohol, and water has no action on it †.

Animé.

6. *Animé.*—This resin is obtained from the *hymenæa courbaril* or locust tree, which is a native of North America. Animé resembles copal very much in its appearance; but is readily soluble in alcohol, which copal is not: this readily distinguishes them. It is said to be very frequently employed in the making of varnishes. Alcohol dissolves it completely. Water, according to the experiments of Neumann, dissolves about $\frac{1}{16}$th of it; and when the decoction is evaporated, it leaves an unctuous mass, which makes the fingers oily. Alcohol distilled over it acquires both the smell

* Neumann's *Chem.* p. 296. † Ibid. p. 295.

Book IV. and taste of animé. Water distilled from it shows on its surface a small quantity of volatile oil *.

Ladanum. 7. *Ladanum* or *labdanum*.—This resin is obtained from the *cystus creticus*, a shrub which grows in Syria and the Grecian Islands. The surface of this shrub is covered with a viscid juice, which, when concreted, forms ladanum. It is collected while moist by drawing over it a kind of rake with thongs fixed to it. From these thongs it is afterwards scraped with a knife. It is always mixed with dust and sand, sometimes in great abundance. The best is in dark coloured masses, almost black, and very soft, having a fragrant odour and a bitterish taste. The impurities, even in the best kinds, amount to about $\frac{1}{4}$th. Water dissolves rather more than $\frac{1}{11}$th of the pure portion, and the matter taken up is said to possess gummy properties. When distilled with water, a small quantity of volatile oil rises. Alcohol likewise comes over impregnated with the taste and smell of labdanum †.

Botany Bay resin. 8. *Botany Bay resin*.—This resin is said to be the produce of the *acarois resinifera*; a tree which grows abundantly in New Holland, especially near Botany Bay. Specimens of it were brought to London about the year 1799, where it was tried as a medicine. Some account was given of it in Governor Philips's Voyage ‡. and in White's Journal of a Voyage to New South Wales ||; but it is to Professor Lichtenstein that we are indebted for an account of its chemical properties. He

* Neumann's *Chem.* p. 297.
† Ibid. p. 295.
‡ Duncan's *New Dispensatory*, p. 60.
|| Appendix, p. 245.

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obtained specimens from London, and published the result of his experiments in Crell's Journal ‡.

Properties.

The resin exudes spontaneously from the trunk of the singular tree which yields it, especially if the bark be wounded. It is at first fluid, but becomes gradually solid when dried in the sun. According to Governor Philips, it is collected usually in the soil which surrounds the tree, having doubtless run down spontaneously to the ground. It consists of pieces of various sizes of a yellow colour, unless when covered with a greenish grey crust. It is firm, yet brittle; and when pounded, does not stick to the mortar nor cake. In the mouth it is easily reduced to powder without sticking to the teeth. It communicates merely a slight sweetish astringent taste. When moderately heated, it melts; on hot coals it burns to a coal, emitting a white smoke, which has a fragrant odour somewhat like storax. When thrown into the fire, it increases the flame like pitch. It communicates to water the flavour of storax, but is insoluble in that liquid. When digested in alcohol, two-thirds dissolve: the remaining third consists of one part of extractive matter, soluble in water, and having an astringent taste; and two parts of woody fibre and other impurities, perfectly tasteless and insoluble. The solution has a brown colour, and exhibits the appearance and the smell of a solution of benzoin. Water throws it down unaltered. When distilled, the products were water, and empyreumatic oil, and charcoal; but it gives no traces of any acid, alkali, or salt, not even when distilled with water.

‡ 1799, ii. 242.

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Action of soda,

And nitric acid.

Twelve parts were boiled in a solution of pu[illegible] in water *. Two parts of the resin were diss[illegible] the remaining ten parts were floating on the s[illegible] cohering together in clots. No crystals were o[illegible] by evaporating part of the solution; and when s[illegible] ric acid was dropt into another portion, resin se[illegible] unaltered. When mixed with twice its weigh[illegible] tric acid, the resin swims unaltered on the s[illegible] but when heat is applied, a considerable efferv[illegible] takes place. The digestion was continued till th[illegible] vescence stopped, and the resin swam on the su[illegible] the liquid collected together in clots. It was t[illegible] parated by filtration. It had lost $\frac{1}{12}$th of its [illegible] The resin thus treated had acquired a bitteris[illegible] was not so easily melted as before, and alcohol [illegible] pable of dissolving only one-half of it. The [illegible] was brown, tasted like bitter almonds; and whe[illegible] ed with water, let fall a yellow resinous precip[illegible] a very bitter taste. The insoluble portion mix[illegible] water, but formed a turbid liquid, which passed t[illegible] the filter. The nitric acid solution separated fr[illegible] resin by filtration was transparent; its colour w[illegible] low; its taste bitter; and it tinged substances d[illegible] it of a yellow colour. By evaporation it yielded [illegible] acid, and deposited a yellow earthy-like powder [illegible] last substance was insoluble in water, and scar[illegible] luble in alcohol. Its taste was exquisitely bitt[illegible] quassia. It mixed with the saliva, and readily [illegible] the skin and paper yellow. The residuum co[illegible]

* By pure *sodasalze*, it is impossible to say whether Lichtens[illegible] the carbonate of soda or pure soda.

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bitter and yellow; but yielded no precipitate with potash and nitrate of lime*.

I have been thus particular in my account of Lichtenstein's experiments, on account of the very curious results which he obtained. Had he employed stronger reagents and greater heat, he would have most probably anticipated the curious discoveries of Hatchett. The bitter substance, into which he converted this resin by nitric acid, deserves particular attention. He suspects that it is capable of producing the same changes on all the resins: a conjecture which he verified with regard to *colophonium*, as he found it to yield equally a yellow bitter substance. We now know from the experiments of Hatchett, that the action of nitric acid on the resins terminates in the formation of artificial tannin, which possesses a very bitter taste.

Black poplar resin.

9. *Black poplar resin.*—In the year 1770 the black poplar was pointed out, in a German periodical work, as a tree from which abundance of wax could be obtained. It was even said, that a manufactory of candles from the wax of this tree had been established in Italy. This account having been revived in 1804, Schrœder was induced to make a set of experiments on the subject. He found, that when the buds of this tree are boiled in water and properly pressed, they yield about ⅛th of their weight of a yellowish white substance, which possesses the properties of a resin, and resembles, according to him, the yellow resin of Botany Bay. When digested in water, a coloured solution is obtained which reddens litmus paper, which becomes

* Lichtenstein, Crell's *Jour.* 1799, ii. 242.

Book IV. muddy by cooling, and which when evaporated deposites small crystals *.

Green resin. 10. The *green resin*, which constitutes the colouring matter of the leaves of trees, and almost all vegetables, is insoluble in water, and soluble in alcohol. From the experiments of Proust we learn, that when treated with oxymuriatic acid it assumes the colour of a withered leaf, and acquires the resinous properties in greater perfection †.

Copal, 11. *Copal.*—This substance, which deserves particular attention from its importance as a varnish, and which at first sight seems to belong to a distinct class from the resins, is obtained, it is said, from the *rhus copallinum*, a tree which is a native of North America; but the best sort of copal is said to come from Spanish America, and to be the produce of different trees. No less than eight species are enumerated by Hernandez ‡.

Copal is a beautiful white resinous substance, with a slight tint of brown. It is sometimes opaque, and sometimes almost perfectly transparent. When heated it melts like other resins; but it differs from them in not being soluble in alcohol, nor in oil of turpentine without peculiar managment. Neither does it dissolve in the fixed oils with the same ease as the other resins. It resembles gum animé a little in appearance; but is easily distinguished by the solubility of this last in alcohol, and by its being brittle between the teeth, whereas animé softens in the mouth §. The specific gravity of copal varies, according to Brisson, from

* Schræder, Gehlen's *Jour.* vi. 598.

† *Jour. de Phys.* lvi. 106.

‡ Lewis, Neumann's *Chem.* p. 299.

§ Ibid.

1·045 to 1·139. Mr Hatchett found it soluble in alkalies and nitric acid with the usual phenomena; so that in this respect it agrees with the other resins. The solution of copal in alkalies he found indeed opalescent, but it is nevertheless permanent. It deserves attention, that he found rosin, when dissolved in nitric acid, and then thrown down by an alkali, to acquire a smell resembling that of copal.

Forms the best varnish.

When copal is dissolved in any volatile liquid, and spread thin upon wood, metal, paper, &c. so that the volatile menstruum may evaporate, the copal remains perfectly transparent, and forms one of the most beautiful and perfect varnishes that can well be conceived. The varnish thus formed is called *copal varnish*, from the chief ingredient in it. This varnish was first discovered in France, and was long known by the name of *vernis martin*. The method of preparing it is concealed; but different processes for dissolving copal in volatile menstrua have been from time to time made public. The following are the most remarkable of these:

Solution in linseed oil.

When copal is kept melted till a sour smelling aromatic odour has ceased to proceed from it, and then mixed with an equal quantity of linseed oil, which has been deprived of all colour by exposure to the sun, it unites with the oil, and forms a varnish which must be dried in the sun *.

Japanners' varnish.

I have been informed by a very ingenious japan manufacturer in Glasgow, that the copal varnish used by the English japanners is made as follows: Four parts by weight of copal in powder are put into a glass ma-

* Dr Black's *Lectures*, ii. 359.

Book IV. trass and melted. The liquid is kept boiling till the fumes, condensed upon the point of a tube thrust into the matrass, drop to the bottom of the liquid without occasioning any hissing noise, as water does. This is a proof that all the water is dissipated, and that the copal has been long enough melted. One part of boiling hot linseed oil (previously boiled in a retort without any litharge) is now poured into it, and well mixed. The matrass is then taken off the fire, and the liquid, while still hot, is mixed with about its own weight of oil of turpentine. The varnish thus made is transparent, but it has a tint of yellow, which the japanners endeavour to conceal by giving the white ground on which they apply it a shade of blue. It is with this varnish that the dial plates of clocks are covered after having been painted white.

Solution in oil of turpentine.

When copal is treated with oil of turpentine in close vessels, the vapour being prevented from escaping, exerts a greater pressure, and the heat rises above the boiling point. This additional heat is said to enable the oil to dissolve the copal. The solution, mixed with a little poppy oil, forms a varnish which is distinguished from the *vernis martin* merely in having a very slight tinge of brown *.

Solution by means of ammonia.

The method of dissolving copal in oil of turpentine, published by Mr Sheldrake, seems to depend upon the same principle with the last solution. On two ounces of copal, broken into small pieces, is poured a mixture of four ounces of ammonia with a pint of oil of turpentine. The whole is kept boiling very gently, so that

* Dr Black's *Lectures*, ii. 359.

the bubbles may be counted as they rise. If the heat be allowed to diminish, or if it be raised too high, the process stops, and cannot be again resumed. The matrass, in which the mixture is boiled, is stopped with a cork, secured in its place by a brass wire, and perforated by a pin. When the copal is nearly dissolved, the process is stopped, and the whole allowed to cool before uncorking the matrass. This varnish has a deep colour; but when spread thin and allowed to dry, it becomes colourless. Its defect is the difficulty with which it dries. This defect Mr Sheldrake remedies by throwing the solution into its own weight of nut oil, rendered drying by white lead, and agitating till the turpentine is separated.

To dissolve copal in alcohol, Mr Sheldrake dissolves half an ounce of camphor in a pint of that liquid, and pours the solution on four ounces of copal. The matrass is placed in a sand bath, and the process is conducted exactly as the one last described. The solution thus formed contains a great deal of copal, and forms a varnish which is perfectly colourless; but considerable heat is necessary to drive off the camphor. And camphor.

Mr Sheldrake has lately favoured the public with another and easier method of dissolving copal. This method is as follows:

"Provide a strong vessel made of tin or other metal; it should be shaped like a wine bottle, and capable of holding two quarts; it will be convenient to have a handle strongly rivetted to the neck; the neck should be long and have a cork fitted to the mouth, but a notch or small hole should be made in the cork, that, when the spirit is expanded by heat, a small portion Sheldrake's process.

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may force its way through the hole, and thus prevent the vessel from bursting.

"Dissolve half an ounce of camphor in a quart of spirit of turpentine, and put it into the vessel; take a piece of copal the size of a large walnut, reduce it to coarse powder or very small pieces; put them into the tin bottle, fasten the cork down with a wire, and set it as quick as possible upon a fire so brisk as to make the spirit boil almost immediately; then keep it boiling very gently for about an hour, when so much of the copal will be dissolved as will make a very good varnish; or, if the operation has been properly begun, but enough of copal has not been dissolved, it may be again put on the fire, and by boiling it slowly for a longer time, it may be at last brought to the consistence desired *."

Demmenie's process.

Van Mons relates another process much simpler than any of the above, which he says was taught him by Mr Demmenie, a Dutch artist. It consists in exposing copal to the action of the steam of alcohol. A long necked matrass is filled one-fourth full of strong alcohol, and a piece of copal is suspended above the surface of the liquid at some little distance; the top of the matrass is covered with a condensator; the alcohol is kept boiling: the copal softens, and drops down into the alcohol like oil. When these drops no longer dissolve, the process must be stopped. The solution thus obtained is perfectly colourless. Copal may be dissolved in oil of turpentine by the same process †.

The following method of making copal varnish has

* Nicholson's *Jour.* ix. 157.

† *Jour. de Chim.* iii. 218.

been recommended by Professor Lenormand. Drop upon the pieces of copal pure essential oil of rosemary. Those pieces that are softened by the oil are fit for the purpose, the others not. Reduce them to a fine powder, put this powder into a glass vessel not thicker than a finger breadth, pour oil of rosemary over it, and stir it about with a glass rod. In a short time the whole is converted into a very thick liquid. Pour alcohol on this liquid by little at a time, incorporating it, by gently agitating the vessel, till it is of the requisite thinness for use *.

Chap. I.

Lenormand's process.

12. *Lac.*—This is a substance deposited on different species of trees in the East Indies, by an insect called *chremes lacca*, constituting a kind of comb or nidus. It has been imported into Europe, and extensively used from time immemorial; but it is only of late years that correct information concerning it has been obtained. For what relates to the natural history of the insect, and the mode of forming the lac, we are indebted to Mr Ker, †, Mr Saunders ‡, and Dr Roxburgh §. Though very often employed in the arts, it was neglected by chemists. Geoffroy junior, indeed, published a dissertation on it, but it contains few chemical experiments. He merely subjected it to distillation, and obtained products which he thought similar to those given by wax in the same circumstances ‖. This led him to consider it as a species of wax, an opinion followed by

History.

* Nicholson's *Jour.* xxiv. 67.

† *Phil. Trans.* 1781, p. 376.

‡ Ibid. 1789, p. 107.

§ Ibid. 1791, p. 228.

‖ *Mem. Par.* 1714, p. 121; and Martine's translation of the *Memoirs of the French Academy*, v. 4.

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Neumann *; but Junker †, and most of the subsequent chemical writers, place it among the resins. Mr Hatchett has lately examined it with his usual address, and ascertained its composition and properties ‡. To him we are indebted for almost every thing which we know respecting its chemical nature.

Varieties.

There are various kinds of lac distinguished in commerce. *Stick lac* is the substance in its natural state, encrusting small twigs. When broken off and boiled in water it loses its red colour, and is called *seed lack*. When melted and reduced to the state of thin crust, it is called *shell lac*. Stick lac is of a deep red colour, and yields to water a substance which is used as a red dye. The other two varieties are brown.

Properties.

Water dissolves the greatest part of the colouring matter of lac, which varies from 15 to ½ *per cent*. Alcohol dissolves the greatest part of the resin, which constitutes the chief ingredient in the composition of lac. Ether acts more feebly. Sulphuric acid dissolves and gradually chars lac; nitric acid dissolves, and then produces the same changes on it as on other resinous bodies. Muriatic and acetic acids likewise act as solvents. A solution of borax in water readily dissolves lac. The best proportions are 20 grains of borax, 100 grains of lac, and four ounces of water. This solution, mixed with lamp black, constitutes Indian ink; and may indeed be employed for many of the purposes of varnish. The fixed alkalies readily dissolve lac, but not the volatile. When placed on a hot iron it

* Chemistry, p. 334. † *Conspectus Chemiæ*, ii. 70.

‡ Analytical Experiments on Lac, *Phil. Trans.* 1804.

melts, and emits a thick smoke with an odour rather pleasant, leaving a spongy coal. When distilled, it yields water slightly acidulous, and a thick butyraceous oil. The gases emitted are a mixture of carbonic acid and carbureted hydrogen. Stick lac yields also some carbonate of ammonia; but the other two varieties none. The following Table exhibits the constituents of the different varieties of lac, according to the analysis of Mr Hatchett.

Chap. I.

Constituents.

	Stick Lac.	Seed Lac.	Shell Lac.
Resin	68	88·5	90·9
Colouring matter	10	2·5	0·5
Wax	6	4·5	4·0
Gluten	5·5	2·0	2·8
Foreign bodies	6·5		
Loss	4·0	2·5	1·8
	100	100	100

The resin is less brittle than those bodies usually are. The colouring matter possesses the properties of extractive; the wax is analogous to myrtle wax, and the gluten closely resembles the gluten of wheat *.

Uses.

The uses to which lac is applied in India are very numerous. In Europe it forms the basis of sealing wax; which is made by melting lac with different proportions of turpentine and some colouring matter, as ivory black, for black sealing wax; vermilion for red, &c. It constitutes also the basis of many varnishes

* Hatchett, *Phil. Trans.* 1804.

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and lackers. This last name indeed is derived fro[m] the word *lac* *.

Amber.

13. *Amber*.—This substance is undoubtedly of v[e]getable origin; and though it differs from resins [in] some of its properties, yet it agrees with them in [so] many others, that it may, without impropriety, be r[e]ferred to them. For the chemical investigation of t[he] properties of this substance, we are chiefly indebted [to] the labours of Hoffmann †, Bourdelin ‡, Stockar [de] Neuforn §, Heyer ||, and more lately it has occupi[ed] the attention of Mr Hatchett. The best account [of] amber varnish which I have seen is by Nils Nystro[m] in the Stockholm Transactions for 1797 **.

Properties.

Amber is a brittle, light, hard substance, usuall[y] nearly transparent; sometimes nearly colourless, b[ut] commonly yellow or even deep brown. It has cons[i]derable lustre. Its specific gravity is 1·065. It [is] tasteless, and without smell, except when pounded [or] heated, when it emits a fragrant odour. When heat[ed] it softens; but, as far as is known, cannot be melt[ed] without losing some of its weight, and altering its a[p-]

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* A detailed account of the method of making several of these is given by Dr Lewis in his *Philosophical Commerce of the Arts*, p. 223.

† *Obs. Phys. Chem.* p. 60. and 198.

‡ *Sur le Succin. Mem. Par.* 1742, p. 192.

§ *Specimen. Chem. Med. Inaugur. de Succino in Genere et Speciatim de S[uc]cino Fossili Wisbolzensi*, 1760. This tract contains a very copious set [of] experiments; which, however, do not always agree with those of ot[her] chemists. Wasserberg's Treatise on Amber is chiefly an abridgment [of] Stockard's.

|| *Chemische versuche mit Bernste'n*, 1787.

** I have seen the paper only through the medium of Crell's Jour[nal]. It is inserted in Crell's *Annals*, 1799, ii. 171. and 253.

pearance. In a strong heat it burns, leaving a small quantity of ashes, the nature of which has not yet been ascertained. Water has no action on it; but alcohol, by long digestion, dissolves about one-eighth of the amber, and forms a coloured solution, which when concentrated becomes milky when mixed with water. The precipitate possesses the properties of a resin. The residuum of the amber is not acted on by alcohol. Though amber be roasted before the action of the alcohol, the tincture is still formed. Hence we learn that the resinons part of amber is not expelled by a melting heat *. When amber is treated with a boiling fixed alkali, it is almost completely dissolved, according to Hoffman, and the compound possesses the qualities of soap; for it is soluble in water and alcohol, and not thrown down by water. Mr Hatchett found that the alkalies act only partially on amber, extracting a yellow tincture. Probably this ingenious chemist did not continue the process long enough; for I have accidentally ascertained, that a weak solution of potash is capable of dissolving amber completely without the assistance of heat, provided it be allowed to act for a sufficient time. I had formed a weak solution of potash (I believe subcarbonate) as nearly as possible of the specific gravity of amber, and I had put into it some amber powder, to show the supposed currents of Count Rumford during the heat of the liquid. On examining the infusion about a month after, I found the amber all lying at the bottom of the phial. I added more alkali to restore the equilibrium. Some time after the

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Action of alkalies,

* Heyer.

amber was again at the bottom, and it was necessary to add more alkali. By this time the solution had acquired a yellow colour. I therefore explained the sinking of the amber, by supposing that the potash had dissolved a portion of it, and that this had altered the specific gravity of the solution. Not knowing at the time that any experiments had been made on the subject, I put aside the phial to ascertain the result. This was three years ago; and at present only two or three particles of the amber at most can be detected, the rest is dissolved completely.

Of acids.

The weaker acids have no action on amber. Sulphuric acid converts it into a black resinous mass. Nitric acid acts upon it; when assisted by heat, nitrous gas is emitted. The amber is first converted into a light resinous substance, and at last dissolves completely. Heyer, who first made this experiment, could obtain neither oxalic nor acetic acid by the action of nitric acid on amber. That nitric acid is really capable of dissolving amber, has been lately verified by the experiments of Hatchett, who found it soluble with the same phenomena as resins in general.

Amber varnish.

Neither fixed nor volatile oils have any action on amber unless it has been previously roasted or exposed to a melting heat. When thus treated, it combines with oils, and the solution forms *amber varnish*. The process recommended by Nystrom is this: Amber is to be spread on a flat bottomed iron pan, and placed on an equal coal fire till it melt; it is then to be withdrawn, covered with a plate of copper and iron, and allowed to cool. If the process be properly conducted, the amber will have lost half of its weight. If the fire be too strong, the amber will be scorched and rendered

useless. If it be too low, the amber will not melt, but be reduced to a brown crust, which answers well enough for a varnish, provided it be exposed to heat till it is reduced to one-half of the original weight. One part of this roasted amber is to be mixed with three parts of linseed oil (rendered drying by litharge and white vitriol), and the mixture exposed to a gentle heat till the amber is dissolved: it is then to be withdrawn from the fire, and when nearly cold four parts of oil of turpentine are to be added. The whole is then allowed to settle, and the clear portion is passed through a linen cloth.

When amber is distilled, there comes over carbureted hydrogen and carbonic acid gas, an acidulous water, then an oil, at first thin and transparent, but becoming gradually darker and thicker. Towards the end of the process the succinic acid sublimes. From the observations of Vogel, it appears that a portion of the yellow matter which is obtained by this distillation possesses the properties of wax very nearly *.

Resin from bitumen.

14. *Resin from bitumen.*—Mr Hatchett ascertained, that when asphalt, mineral caoutchouc, and other similar bodies, are digested a sufficient time in nitric acid, they furnish a considerable portion of a brown substance, which possesses many of the properties of resins. Kilkenny coal, and every other variety of coal which contains no bitumen, is converted by nitric acid into artificial tannin, but yields no resin; while common coal furnishes both. Thus it appears that bitumen, when treated with nitric acid, has the property of yielding a species of resin.

* Gehlen's *Jour.* v. 272.

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Properties.

This substance has a pale brown colour like that of Spanish snuff; its internal fracture is dark brown, and it has a resinous lustre. When heated it does not readily melt; but when inflamed emits a resinous odour, mixed with that of fat oils, and leaves a coal much more bulky than the original substance. Alcohol dissolves it. Water throws down a part from the solution; but a portion remains undissolved, which acts on reagents like *extractive*. The taste is bitter. Hence this substance appears to be intermediate between extractive and resin. When digested with nitric acid it is readily converted into artificial tannin; and when digested with sulphuric acid it is converted into charcoal *.

I have now enumerated the most remarkable of the resinous bodies with which we are acquainted. There are indeed many of the substances employed in medicine, which undoubtedly contain resins; for example, *aloes*, *jalap*, *snake root*, *arnica*, &c.; but as these have not yet been chemically examined, it would be in vain to dwell upon them.

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* Hatchett's Third Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

SECT. XXIV.

OF GUAIACUM.

THIS substance is obtained from the *guaiacum officinale*, a tree which is a native of the West Indies, and yields a very hard heavy wood. The resin exudes spontaneously, and is also driven out artificially by heating one end of the wood in billets previously bored longitudinally; the melted resin runs out at the extremity farthest from the fire. This substance has been used in medicine for a considerable time, having been originally recommended in venereal diseases. Nothing is known concerning its original introduction into Europe. Origin.

It was considered by chemists as a resin, till Mr Hatchett observed, that when treated with nitric acid it yielded products very different from those of resinous bodies *. This induced Mr William Brande to examine its chemical properties in detail †. To his valuable paper we are indebted for almost all the accurate information which we possess respecting its chemical nature.

1. Guaiacum is a solid substance, resembling a resin in appearance. Its colour differs considerably, being Properties.

* Second Series of Experiments on Artificial Tannin, *Phil. Trans.* 1805.

† Chemical Experiments on Guaiacum, *Phil. Trans.* 1806, and *Phil. Mag.* xxv. 105.

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partly brownish, partly reddish, and partly greenish; and it always becomes green when left exposed to the light in the open air*. It has a certain degree of transparency, and breaks with a vitreous fracture. When pounded it emits a pleasant balsamic smell, but has scarcely any taste, although when swallowed it excites a burning sensation in the throat. When heated it melts, and diffuses at the same time a pretty strong fragrant odour. Its specific gravity is 1·2289†.

Action of water,

2. When guaiacum is digested in water a portion of it is dissolved, the water acquiring a greenish brown colour and a sweetish taste. The liquid, when evaporated, leaves a brown substance, which possesses the properties of *extractive;* being soluble in hot water and alcohol, but scarcely in sulphuric ether, and forming precipitates with muriates of alumina, tin, and silver. This extractive amounts to about nine parts in the hundred of guaiacum‡.

Alcohol.

3. Alcohol dissolves guaiacum with facility, and forms a deep brown coloured solution. Water renders this solution milky by separating the resin. Muriatic acid throws down the guaiacum of an ash grey, and sulphuric acid of a pale green colour. Acetic acid and the alkalies occasion no precipitate. Liquid oxymuriatic acid throws it down of a fine pale blue, which does not change when dried. Diluted nitric acid occasions no change at first; but after some hours the liquid becomes green, then blue, and at last brown, and at that period a brown coloured precipitate falls down

* Wollaston, Nicholson's *Jour.* viii. 294.
† Brande, *Phil. Mag.* xxv. 105. ‡ Id. Ibid.

If water be mixed with the liquid when it has assumed a green or a blue colour, green and blue precipitates may be respectively obtained *. Chap. I.

3. Sulphuric ether does not act so powerfully on guaiacum as alcohol. The solution obtained by means of it, exhibits the same properties when treated with reagents as that in alcohol †. Ether,

4. The alkaline solutions, both pure and in the state of carbonates, dissolve guaiacum with facility. Two ounces of a saturated solution of potash dissolved about 65 grains of guaiacum; the same quantity of ammonia only 25 grains; or guaiacum dissolves in about 15 parts of potash and 38 parts of ammonia. Nitric acid threw down from these solutions a brown precipitate, similar to what is obtained when the alcoholic solution is mixed with the same acid. Muriatic acid and diluted sulphuric acid throw down a flesh-coloured curdy precipitate, which in its properties approaches the nature of extractive ‡. Alkalies.

5. Most of the acids act upon guaiacum with considerable energy. Action of acids.

Sulphuric acid dissolves it, and forms a deep red liquid, which deposites while fresh a lilac-coloured precipitate when mixed with water. When heat is applied the guaiacum is charred.

Nitric acid dissolves guaiacum completely without the assistance of heat, and with a strong effervescence. When the solution is evaporated, it yields a very large

* Brande, *Phil. Mag.* xxv. 106. † Id. Ibid.
‡ Id. Ibid. p. 109.

Book IV. quantity of oxalic acid *. No artificial tannin appears to be formed, but rather a substance possessing the properties of extractive. Diluted nitric acid converts guaiacum into a brown substance, similar to the precipitate obtained by nitric acid from the alcoholic solution of guaiacum. This brown matter possesses the properties of a resin †.

Muriatic acid acts but slightly, as the guaiacum soon melts into a blackish mass, which is not acted upon ‡.

Distillation. 6. When guaiacum is distilled, 100 parts of it yielded to Mr Brande the following products:

Acidulous water........................	5·5
Thick brown oil........................	24·5
Thin empyreumatic oil................	30·0
Charcoal..................................	30·5
Gases, consisting of carbonic acid and carbureted hydrogen	9·5
	100·0

The coal when incinerated left three grains of lime, but no alkaline substance §.

7. Such are the properties of guaiacum, as far as they have been hitherto ascertained. From the preceding detail, it is obvious that guaiacum in many respects coincides with the resins; but it differs from them in three particulars so remarkable, that we cannot avoid considering it as a distinct substance.

Peculiar properties. The first of these is the great quantity of charcoal which it leaves when distilled in close vessels. This

* Hatchett, Second Series of Experiments on Artificial Tannin, Phil. Trans. 1806.

† Brande, Phil. Mag. xxv. p. 107.

‡ Id. Ibid. p. 107.

§ Id. Ibid.

Mr Brande found to amount to above 30 *per cent.*; while the resins, in like circumstances, hardly ever leave more than 15 *per cent.* of charcoal, and often not nearly so much. It is possible, however, and indeed not improbable, that this difference is to be ascribed to the different degrees of heat employed. Chap. I.

The second peculiarity is the action of nitric acid on guaiacum. This acid does not dissolve the resins without the assistance of heat, but converts them into a brown brittle mass; whereas it dissolves guaiacum completely. The action of this acid on the resins terminates in the formation of artificial tannin, whereas its action on guaiacum terminates in the formation of oxalic acid. This striking difference is alone sufficient to warrant a separation of guaiacum from the resins.

The third peculiarity is the remarkable suite of changes of colour which guaiacum undergoes when its solutions are treated with nitric and oxymuriatic acids. Dr Wollaston first observed that guaiacum becomes green when exposed to light, provided air have access to it; and that the colour is again removed by the application of heat *. Hence it is probable that oxygen occasions the change. This opinion is much strengthened by the experiments of Mr Brande. When guaiacum was put in contact with oxygen gas, it became green sooner than in the open air. When put into oxymuriatic gas it became first green, then blue, and lastly brown; and ammonia, when left in contact with it, restored again its green colour. In like manner, by treating the alcoholic solution of guaiacum

Forms oxides.

* Nicholson's *Jour.* viii. 195.

Book IV. with nitric acid, green, blue, and brown precipitates obtained, according to the length of time that the is allowed to act upon it. These facts give consi able plausibility to the opinion of Mr Brande, that changes of colour are owing to the combinations of ‹ gen with the guaiacum; that the green contains least, and the brown the most oxygen, while the is intermediate *. Thus guaiacum, in its chang colour, bears some resemblance to indigo. Mr Br has remarked a coincidence also between guaia and the green resin of the leaves of plants.

SECT. XXV.

OF BALSAMS.

The term *balsam* or *balm* was originally confine a thick fragrant juice obtained from the *amyris G densis*, and afterwards applied by chemists to all stances which possessed the same degree of cor ence and a strong smell, whether natural or artifi Bucquet restricted the term to those resinous-like stances which yield benzoic acid when heated. new meaning of the word, which has been adopte chemists in general, has introduced into the cla balsams several substances which were formerly sidered as resins. The word *balsam* originally im

* Brande, *Phil. Mag.* xxv. 107.

a substance possessing a certain degree of fluidity; but now there are two classes of balsams; the one fluid, and the other solid and brittle.

Definition.

A balsam, then, is a substance which possesses the general properties of a resin; but which, when heated or digested in acids, yields a portion of benzoic acid. Chemists, in general, have considered them as combinations of a resin with benzoic acid; but Mr Hatchett has made it probable, that the acid is formed at the time of its separation *.

Properties.

They are insoluble in water; but when boiled in that liquid often give out a portion of benzoic acid. Alcohol and ether dissolve them readily. The strong acids likewise dissolve them; and during the solution a portion of benzoic acid is separated. Nitric acid, in some cases, evolves likewise traces of prussic acid. The alkalies act upon them nearly as on the resins.

Division.

They may be divided into two classes; namely, *liquid* and *solid* balsams.

I. Liquid Balsams.

The liquid balsams at present known are five in number; namely,

1. Opobalsamum	4. Peru
2. Copaiva	5. Styrax.
3. Tolu	

Opobalsamum.

1. *Opobalsamum* or *balm of Gilead*.—This balsam is obtained from the *amyris Gileadensis*, a tree which grows in Arabia, especially near Mecca. It is so much valued by the Turks that it is seldom or never import-

* Second Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

Book IV. ed into Europe. We are of course ignorant of its composition. It is said to be at first turbid and white, and of a strong aromatic smell, and bitter, acrid, astringent taste; but by keeping, it becomes limpid and thin, and its colour changes first to green, then to yellow, and at last it assumes the colour of honey, and the consistence of turpentine *.

Copaiva

2. *Copaiva.*—This balsam is obtained from the *copaifera officinalis*; a tree which grows in South America, and some of the West Indian islands. It exudes from incisions made in the trunk of the tree. The juice thus obtained is transparent, of a yellowish colour, an agreeable smell, a pungent taste, at first of the consistence of oil, but it gradually becomes as thick as honey. Its specific gravity is 0·950 †. When mixed with water and distilled, there comes over with the water a very large portion of volatile oil. Lewis obtained half the original weight of this oil ‡. Schonberg, from eight ounces of copaiva, obtained 3½ of oil by this process §. It was colourless, very limpid, of the specific gravity 0·900; had the taste and smell of copaiva, but rather stronger. It dissolved in eight parts of alcohol; but the copaiva itself is a good deal more soluble ‖. The oil ceases to come over before all the water has passed into the receiver. The residuum, of course, consists of two substances; namely, the watery portion, and a greyish yellow substance, lying at the bottom of the vessel, which, on exposure to the air, dries, and becomes brittle and transparent. When

Yields oil

and resin;

* This is the account of Professor Alpinus, as quoted by Lewis, Neumann's *Chem.* p. 284.

† Schonberg, Gehlen's *Jour.* vi. 494.

‡ Neumann's *Chem.* p. 285.

§ Gehlen's *Jour.* vi. 494.

‖ Schonberg, Ibid.

heated it melts, and possesses the characters of a resin. When distilled it yielded a yellowish thick oil, some acidulous water, and a gas; one-sixth of which was carbonic acid, and the remainder seemed to possess the characters of olefiant gas *. From these facts, which have been long known, it was concluded, that copaiva is a compound of a resin and a volatile oil, which passes over at a heat inferior to that of boiling water; but the experiments of Schonberg have rendered it much more probable, that the balsam is decomposed when distilled along with water, and that both the oil and resin are new products.

But is decomposed.

Distillation.

When distilled on a water bath, nothing comes over but a few drops of water, and one or two drops of oil †. If the vessel be kept at a temperature between 284° and 257°, scarcely any thing more is obtained than when the distillation is conducted over a water bath. At the temperature of 504° the balsam begins to boil gently, a gas is extricated, and drops begin to pass more rapidly into the receiver. At 550° it boils briskly, and the distillation goes on rapidly. There passes into the receiver a limpid yellowish oil, occasionally mixed with a drop or two of water. As the distillation proceeds the oil becomes more and more yellow. At this period the balsam is as liquid as water, and boils without any frothing or swelling. After this period the oil becomes yellow, and then brownish red; but still continues pretty thin. The first oil obtained by Schonberg from four ounces of copaiva, by this process, was $3\frac{1}{18}$ ounces. The water had a sour taste, and redden-

* Schonberg, Gehlen's *Jour.* vi. p. 497. † Id. Ibid. p. 495.

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ed litmus paper. The gas amounted to 81 ou measures; $\frac{1}{7}$th of it was carbonic acid, the rest res bled olefiant gas *.

Action of nitric acid,

Nitric acid acts upon this balsam with consider energy. When one part of the balsam is mixed w four parts of nitric acid and two parts of water, heated, a yellowish solution is formed, similar to original balsam, but darker. When distilled, th comes over with the liquid that passes into the ceiver an apple-green oil, which lines the helm of retort. The nature of the residue was not examin Doubtless it would have been found to contain artifi tannin, provided a sufficient quantity of acid was e ployed †.

Similar to turpentine.

When treated with sulphuric acid, it yields a port of artificial tannin ‡.

Whether this balsam yields benzoic acid has been ascertained. Its properties are rather against probability of its doing so. Indeed it bears a strik resemblance to turpentine in many respects; and oug along with it, to constitute a class of bodies interr diate between volatile oils and resins, to which name of *turpentines* might be given.

Balsam of tolu.

3. *Balsam of Tolu.*—This substance is obtained fr the *toluifera balsamum*, a tree which grows in So America. The balsam flows from incisions made the bark. It comes to Europe in small gourd she It is of a reddish brown colour and considerable c

* Schouberg, Gehlen's *Jour.* vi. 495. † Id. Ibid. p. 499.

‡ Hatchett, Third Series of Experiments on Artificial Tannin, *Trans.* 1806.

sistence; and when exposed to the air, it becomes solid and brittle. Its smell is fragrant, and continues so even after the balsam has become thick by age. When distilled with water, it yields very little volatile oil, but impregnates the water strongly with its taste and smell. A quantity of benzoic acid sublimes, if the distillation be continued *.

Chap. I.

Action of alkalies,

Mr Hatchett found it soluble in the alkalies, like the rest of the balsams. When he dissolved it in the smallest possible quantity of lixivium of potash, it completely loses its own odour, and assumes a most fragrant smell, somewhat resembling that of the clove pink. "This smell," Mr Hatchett observes, "is not fugitive, for it is still retained by a solution which was prepared in June, and has remained in an open glass during four months."

And acids.

When digested in sulphuric acid, a considerable quantity of pure benzoic acid sublimes. When the solution of it in this acid is evaporated to dryness, and the residue treated with alcohol, a portion of artificial tannin is obtained; the residual charcoal amounts to 0·54 of the original balsam †.

Mr Hatchett found that it dissolved in nitric acid with nearly the same phenomena as the resins; but it assumed the odour of bitter almonds, which leads him to suspect the formation of prussic acid. During the solution in nitric acid, a portion of benzoic acid su-

* Lewis, Neumann's *Chem.* p. 285.

† Hatchett, Third Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

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blimes. By repeated digestions it is converted into artificial tannin *.

Balsam of Peru.

4. *Balsam of Peru.*—This substance is obtained from the *myroxylon peruiferum*, which grows in the warm parts of South America. The tree is full of resin, and the balsam is obtained by boiling the twigs in water. It has the consistency of honey, a brown colour, an agreeable smell, and a hot acrid taste. When boiled with water for some time, the liquid separated by the filter reddens vegetable blues, and deposites crystals of benzoic acid on cooling. The water contains no other substance †. When distilled with water, it yields a very small quantity of reddish limpid oil. Hoffmann obtained only one part of oil from 16 of balsam ‡. Lichtenberg mixed two ounces of balsam with eight of water, and distilled. The first two ounces of water came over colourless, and had only a slight odour of the balsam. The next three were milky, smelt strongly of the balsam, and at the bottom of the receiver were some drops of colourless oil. The next $1\frac{1}{2}$ ounces were similar, but contained more oil. Between 50 and 60 grains of benzoic acid had sublimed into the neck of the retort. By increasing the heat $3\frac{1}{2}$ drachms of yellow oil came over, and a quantity of benzoic acid. A black shining coal remained in the retort §.

Action of heat.

When this balsam is exposed to the heat of a water bath, only a drop or two of water and a few drops of

* Hatchett, Second Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

† Lichtenberg, Gehlen's *Jour.* vi. 489.

‡ *Observ. Phys. Chym. Select.* p. 71.

§ Gehlen's *Jour.* vi. 485.

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an be obtained *. When placed in a sand bath, exposed to a temperature gradually raised, nothing e comes over till the balsam is heated to 300°, when rtion of benzoic acid sublimes; and at 324°, drops vater and oil began to come over. At 550° the am begins to boil, and some gas is disengaged. At ° the oil (mixed with a little water) comes over ty fast. At 617° it comes over still more rapidly. htenberg, to whom we owe these experiments, kept ounces of balsam at that temperature for two rs, and obtained two ounces of a yellowish oil, and rystallized mass of benzoic acid, which, together h the water, weighed $6\frac{1}{2}$ drachms. The gas obtained ounted to 58 ounce measures; of these, 38 were bonic acid. The rest burnt like olefiant gas. By reasing the heat a brownish oil came over, and at last lack oil of the consistence of pitch, and 49 ounce asures of gas were extricated. Of these, six were bonic acid; the residue burnt with a bluish white me †.

Of alkalies.

A saturated solution of carbonate of soda forms with s balsam a thick mass. When diluted with water d heated, a portion is dissolved. The solution, when urated with sulphuric acid, deposites crystals of benic acid. One part of the balsam, treated with one rt of potash dissolved in four parts of water, formd an opaque solution, which gradually separated into wo portions: the uppermost, a clear oil with some rey flakes at its lower surface; the undermost, a dark rownish red opaque solution. This last solution,

* Lichtenberg, Gehlen's *Jour.* vi. 485. † Ibid. p. 487.

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when saturated with sulphuric acid, lets fall a resin like substance, dissolved by boiling, while benzoic crystallized *.

Of acids.

Nitric acid acts upon the balsam with energy, gives it an orange yellow colour when assisted by l When distilled with a sufficient quantity of this diluted, the liquid in the receiver smells of bitte monds. When supersaturated with carbonate of pot and mixed with a solution of iron, a precipitate i which, when treated with muriatic acid, leaves pru blue, and indicates the presence of prussic acid. ring the distillation benzoic acid sublimes. The due in the retort has a crystalline appearance, is l yellow, dissolves sparingly in boiling water, and pr pitates on cooling in the state of a yellow powd Such was the result of Lichtenberg's trials. Mr l chett observed that the residue possessed the prope of artificial tannin.

When this balsam is treated with sulphuric acid, tificial tannin is also formed, and the residual char amounts to no less than 0·64 of the original weig the balsam ‡.

Styrax.

5. *Styrax*.—This is a semifluid juice, said to be tained from the *liquidambar styraciflua*, a tree wh grows in Virginia, Mexico, and some other parts America §. It is prepared, according to Mr Peti in the island Cobross in the Red Sea, from the b

* Lichtenberg, Gehlen's *Jour.* vi. 487. † Gehlen's *Jour.* vi.

‡ Hatchett, Third Series of Experiments on Artificial Tannin, *Trans.* 1806.

§ Lewis, Neuman's *Chemistry*, p. 291.

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of a tree called *rosa mallos* by the natives, and considered by botanists as the same with the American species. The bark of this tree is boiled in salt water to the consistence of bird-lime, and then put into casks*. Bouillon la Grange has published an account of its properties †. Its colour is greenish, and its taste aromatic, and its smell agreeable. It is easily volatilized by heat. When treated with water, benzoic acid is dissolved. It is totally soluble in alcohol except the impurities. When exposed to the air it becomes harder, and absorbs oxygen. When distilled, it yields an acidulous water, having the odour of benzoic acid, a limpid colourless hot oil, a solid coloured oil, benzoic acid, and a mixture of carbonic acid and carbureted hydrogen. The charcoal is light and contains some oil.

II. Solid Balsams.

The solid balsams at present known are only three in number; namely,

1. Benzoin
2. Storax
3. Dragon's blood

Benzoin.

1. *Benzoin.*—This substance is the produce of the *styrax benzoe*, a tree which grows in Sumatra, &c. and which has been described by Dr Dryander ‡. Benzoin is obtained from this tree by incision; a tree yielding three or four pounds. It is a solid brittle substance, sometimes in the form of yellowish white tears joined

* *Phil. Trans.* 1708, vol. xxvi. p. 44. † *Ann. de Chim.* xxvi. 203.
‡ *Phil. Trans.* 1787, p. 307.

together by a brown substance, and sometimes in the form of a brown substance not unlike common rosin. It has a very agreeable smell, which is increased by heating the benzoin. It has little taste. Its specific gravity is 1·092. This substance has been used in medicine for ages, and various processes have been pointed out by chemists for extracting benzoic acid from it; but the only person who has examined its properties in detail is Mr William Brande*.

Cold water has very little effect on benzoin, but boiling water takes up a portion of benzoic acid.

Action of alcohol,

Alcohol dissolves it when assisted by a gentle heat, and forms a deep yellow solution inclining to reddish brown. When this solution is diluted with water, the benzoin precipitates in the form of a white powder. It is precipitated also by muriatic and acetic acids, but not by the alkalies. A few drops of sulphuric acid likewise precipitate the benzoin; but an additional quantity redissolves it, and forms a liquid of the colour of port wine. When equal quantities of the alcoholic solution of benzoin and sulphuric acid are mixed, a dark pink precipitate falls. The liquid assumes a pink colour which becomes lilac when diluted with water. Nitric acid occasions a strong effervescence, and forms a dark red fluid with the alcoholic solution, but throws down no precipitate †.

Ether,

Ether dissolves benzoin with facility, and the solution with reagents exhibits the same phenomena as the alcoholic ‡.

Acids,

Nitric acid acts with violence on benzoin, and

* Nicholson's *Jour.* x. 82. † Brande, Ibid. ‡

verts it into an orange-coloured mass. When assisted by heat the acid dissolves the benzoin; and as the solution cools, crystals of benzoic acid gradually separate. Mr Hatchett ascertained that by this process a quantity of artificial tannin is formed.

Sulphuric acid dissolves benzoin, while benzoic acid (as Hatchett discovered) sublimes; the solution is at first a deep red. By continuing the digestion, a portion of artificial tannin is formed, and the charcoal evolved amounts to 0·48 of the benzoin dissolved *.

Acetic acid dissolves benzoin without the assistance of heat. When heat is applied, the solution, as it cools, becomes turbid; owing to the separation of benzoic acid †.

Benzoin is dissolved by a boiling lixivium of the fixed alkalies; a dark brown solution is formed, which becomes turbid after some days exposure to the air. Ammonia likewise dissolves benzoin sparingly ‡.

When Mr Brande exposed 100 grains of benzoin in a retort to a heat gradually raised to redness, the products were,

Benzoic acid	9·0
Acidulous water	5·5
Butyraceous and empyreumatic oil	60·0
Charcoal	22·0
Carbureted hydrogen and carbonic acid	3·5
	100·0

2. *Storax.*—This is the most fragrant of all the bal-

* Hatchett, Third Series of Experiments on Artificial Tannin.
† Brande, Nicholson's *Jour.* x. 86.
‡ Ibid. p. 86.

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sams, and is obtained from the *styrax officinalis*, a tree which grows in the Levant, and it is said also in Italy. Sometimes it is in the state of red tears; and this is said to be the state in which it is obtained from the tree. But common storax is in large cakes; brittle, but soft to the touch, and of a reddish brown colour. This is more fragrant than the other sort, though it contains a considerable mixture of saw-dust. It dissolves in alcohol. When distilled with alcohol or with water, scarcely any oil is obtained. When distilled by the naked fire, it seems, from the experiments of Neumann, to yield the same produc's as benzoin *.

Dragon's blood.

3. *Dragon's blood.*—This is a brittle substance of a dark red colour, which comes from the East Indies. There are two sorts of it; one in small oval drops or tears of a fine deep red, which becomes crimson when the tears are reduced to powder; the other is in larger masses, some of which are pale red, and others dark. It is probably obtained from different kinds of trees; the *calamus draco* is said to furnish most of what comes from India. The *dracæna draco* and the *pterocarpus draco* are also said to furnish it.

Properties.

Dragon's blood is brittle and tasteless, and has no sensible smell. Water does not act upon it, but alcohol dissolves the greatest part, leaving a whitish red substance, partially acted upon by water. The solution has a fine deep red colour, which stains marble, and the stain penetrates the deeper the hotter the marble is. It dissolves also in oils, and gives them a deep red colour also. When heated it melts, catches flame, and

* Neumann's *Chem.* p. 290.

† Lewis, Ibid. p. 299.

emits an acid fume similar to that of benzoic acid *. When digested with lime, a portion of it becomes soluble in water, and it acquires a balsamic odour. On adding muriatic acid to the solution, a red resinous substance is precipitated, and slight traces of benzoic acid only become perceptible †. Nitric acid acts upon it with energy, changes it to a deep yellow, a portion of benzoic acid is sublimed, and a brown mass remains soluble in water, and possessing the properties of artificial tannin ‡. When treated with sulphuric acid no perceptible portion of benzoic acid sublimes; but it is converted partly into artificial tannin, while a quantity of charcoal is evolved, amounting to 0·48 of the original dragon's blood employed §. Chap. I.

SECT. XXVI.

OF CAOUTCHOUC.

About the beginning of the 18th century, a substance called *caoutchouc* was brought as a curiosity from America. It was soft, wonderfully elastic, and very combustible. The pieces of it that came to Europe History.

* Lewis, Neumann's *Chem.* p. 299.

† Hatchett, Second Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

‡ Hatchett, Ibid.

§ Hatchett, Third Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

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were usually in the shape of bottles, birds, &c. Th substance is very much used in rubbing out the marl made upon paper by a black lead pencil; and therefo in this country it is often called *Indian rubber*. N thing was known of its production, except that it w obtained from a tree, till the French academicians we to South America in 1735 to measure a degree of t meridian. Mr de la Condamine sent an account of to the French Academy in the year 1736. He to them, that there grew in the province of Esmeraldas, Brazil, a tree, called by the natives *Hbevé*; that fro this tree there flowed a milky juice, which, when i spissated, was *caoutchouc*. Don Pedro Maldonado, w accompanied the French academicians, found the sa tree on the banks of the Maragnon; but he died so after, and his papers were never published. Mr Fre nau, after a very laborious search, discovered the sa tree in Cayenne. His account of it was read to t French Academy in 1751.

Plants yielding it.

It is now known that there are at least two trees South America from which caoutchouc may be obtai ed; the *hævea caoutchouc*, and the *jatropha elastica* and it is exceedingly probable that it is extracted al from other species of *hævea* and *jatropha*. Seve trees likewise which grow in the East Indies yie caoutchouc; the principal of these are, the *ficus in ca*, the *artocarpus integrifolia*, and the *urceola ela tica*; a plant discovered by Mr Howison, and first d scribed and named by Dr Roxburgh *.

When any of these plants is punctured, there exud

* *Asiatic Researches*, v. 167. London edition.

from it a milky juice, which, when exposed to the air, gradually lets fall a concrete substance, which is caoutchouc. Chap. I.

If oxymuriatic acid be poured into the milky juice, the caoutchouc precipitates immediately, and at the same time the acid loses its peculiar odour. This renders it probable that the formation of the caoutchouc is owing to its basis absorbing oxygen *. If the milky juice be confined in a glass vessel containing common air, it gradually absorbs oxygen, and a pellicle of caoutchouc appears on its surface †.

Caoutchouc was no sooner known than it drew the attention of philosophers. Its singular properties promised that it would be exceedingly useful in the arts, provided any method could be fallen upon to mould it into the various instruments for which it seemed peculiarly adapted. Messrs de la Condamine and Fresnau had mentioned some of its properties; but Macquer was the first person who undertook to examine it with attention. His experiments were published in the Memoirs of the French Academy for the year 1768. They threw a good deal of light on the subject; but Macquer fell into some mistakes, which were pointed out by Mr Berniard, who published an admirable paper on caoutchouc in the 17th volume of the *Journal de Physique*. To this paper we are indebted for the greater number of facts at present known respecting caoutchouc. Mr Grossart and Mr Fourcroy having likewise added considerably to our knowledge of this singular sub-

* Fourcroy, *Ann. de Chim.* xi. 259.

† Ibid.

stance; both of their treatises have been published in the 11th volume of the *Annales de Chimie*.

Caoutchouc, when pure, is of a white colour *, and without either taste or smell. The blackish colour of the caoutchouc of commerce is owing to the method employed in drying it after it has been spread upon moulds. The usual way is to spread a thin coat of the milky juice upon the mould, and then to dry it by exposing it to smoke; afterwards another coat is spread on, which is dried in the same way. Thus the caoutchouc of commerce consists of numerous layers of pure caoutchouc alternating with as many layers of soot.

Caoutchouc is soft and pliable like leather. It is exceedingly elastic and adhesive; so that it may be forcibly stretched out much beyond its usual length, and instantly recover its former bulk when the force is withdrawn. It cannot be broken without very considerable force. Its specific gravity is 0·9335 †.

icity g to t heat. To that acute philosopher Mr Gough of Manchester, I am indebted for some very important experiments on the connexion between the temperature of caoutchouc and its elasticity. They have been since published in the second volume of the Manchester Memoirs, second series. It is necessary to premise, that Mr Gough has been blind from an infant, and that therefore his sense of touch is peculiarly delicate; so much so, that he is an excellent botanist, and can distinguish plants with the utmost certainty by the feel: a power so extraordinary,

* I have some pieces of it from the East Indies which had been allowed to inspissate in the open air. They are white, with a slight cast of yellow, and have very much the appearance and feel of white soap.

† Brisson.

that we who enjoy the advantage of sight can scarcely conceive how it can be acquired. Mr Gough's experiments are as follows:

Take a thong of this substance two or three inches long, and a few lines in breadth and thickness; put it in warm water till it becomes quite pliant: then, holding it merely extended between the two hands, bring the edge of it in contact with the lips, and observe the temperature (of the variations of which that part of the face is a very nice judge); then remove the thong a few lines from the lips, and stretch it forcibly, and bring it again in contact with the lips, and a very sensible increase of temperature will be perceived. Allow it to relax to its former state, and the temperature will be perceived immediately to sink. If we stretch the thong again, and then plunge it immediately into cold water, keeping it extended for a minute or more in the liquid, on letting go one end it will be found to have lost much of its contractile power; for it will not return to its former dimensions. But if we plunge it into warm water, or warm it by holding it for some time in the shut hand, it will begin to contract again, and soon return to its former figure and size. These experiments are of great importance, as they furnish a very palpable and convincing proof that ductility is owing to latent heat as well as fluidity. They afford a fine illustration of Dr Black's theory of latent heat. We see clearly that the elasticity of caoutchouc and the ductility of metals are different cases of one and the same thing.

Caoutchouc is not altered by exposure to the air; it is perfectly insoluble in water: but if boiled for some time its edges become somewhat transparent, owing un-

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doubtedly to the water carrying off the soot; and so soft, that when two of them are pressed and kept together for some time, they adhere as closely as if they formed one piece. By this contrivance pieces of caoutchouc may be soldered together, and thus made to assume whatever shape we please *.

Action of alcohol.

Caoutchouc is insoluble in alcohol. This property was discovered very early, and fully confirmed by the experiments of Mr Macquer. The alcohol, however, renders it colourless.

Ether.

Caoutchouc is soluble in ether. This property was first pointed out by Macquer. Berniard, on the contrary, found that caoutchouc was scarcely soluble at all in sulphuric ether, which was the ether used by Macquer, and that even nitric ether was but an imperfect solvent. The difference in the results of these two chemists was very singular; both were remarkable for their accuracy, and both were too well acquainted with the subject to be easily misled. The matter was first cleared up by Mr Cavallo. He found that ether, when newly prepared, seldom or never dissolved caoutchouc completely; but if the precaution was taken to wash the ether previously in water, it afterwards dissolved caoutchouc with facility. Mr Grossart tried this experiment, and found it accurate †. It is evident from this that these chemists had employed ether in different states. The washing of ether has two effects. It deprives it of a little alcohol with which it is often impreg-

* Grossart, *Ann. de Chim.* xi. 153. See a method of making caoutchouc tubes by means of this property, *Phil. Mag.* xxii. 340.

† Grossart, *Ann. de Chim.* xi. 147.

mated, and it adds to it about one-tenth of water, which remains combined with it. Alcohol precipitates the caoutchouc from this solution. Chap. I.

When the ether is evaporated, the caoutchouc is obtained unaltered. Caoutchouc, therefore, dissolved in ether, may be employed to make instruments of different kinds, just as the milky juice of the *hævea*; but this method would be a great deal too expensive for common use.

Oils, Caoutchouc is soluble in volatile oils*; but, in general, when these oils are evaporated, it remains somewhat glutinous, and therefore is scarcely proper for those uses to which, before its solution, it was so admirably adapted.

Alkalies, It is said by Berniard to be insoluble in alkalies; but I find upon trial that this is a mistake. I was led to make the experiment by an accident. I employed a caoutchouc bottle fitted with a stop-cock in the usual way for holding ammoniacal gas. The gas very soon disappeared, though the bottle was perfectly air-tight, as I learned by plunging it in water. This induced me to fill it repeatedly with gas. In a short time it became evident that the gas had been absorbed by the bottle itself. It became soft and then glutinous, and never recovered its elasticity. I then tried the alkalies in general, and found that they were all capable of producing the same changes on caoutchouc, and even of dissolving it, though in a very minute proportion.

Acids, The acids act but feebly upon caoutchouc. Sulphuric acid, even after a very long digestion, only chars it

* Berniard.

Book IV. superficially. The proportion of charcoal obtained in Mr Hatchett's experiments was only 12 *per cent.* and he could observe no traces of artificial tannin *. But when heat is applied the caoutchouc is completely decomposed. When treated with nitric acid, there came over azotic gas, carbonic acid gas, prussic acid gas; and oxalic acid is said to be formed †. Muriatic acid does not affect it ‡. The other acids have not been tried.

Heat. Fabroni has discovered, that rectified petroleum dissolves it, and leaves it unaltered when evaporated §.

When expoosed to heat it readily melts; but it never afterwards recovers its properties, but continues always of the consistence of tar. It burns very readily with a bright flame, and diffuses a fetid odour. In those countries where it is produced, it is often used by way of candle.

When distilled it gives out ammonia ‖. It is evident from this, and from the effect of sulphuric and nitric acid upon it, that it is composed of carbon, hydrogen, azote, and oxygen; but the manner in which they are combined is unknown.

Plants containing it. It seems to exist in a great variety of plants; but is usually confounded with the other ingredients. It may be separated from resins by means of alcohol. It may be extracted from the different species of missletoe by water, with which, in the fluid state in which it exists in these plants, it readily combines. When mixed with gum or extractive, it may be separated by the following process: Digest a part of the plant containing it first in

* Third Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806. † *Ann. de Chim.* xi. 232. ‡ Berniard.

§ *Ann. de Chim.* xi. 195.; and xii. 156. ‖ Ibid. xi. 232.

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water and then in alcohol, till all the substances soluble in these liquids are extracted. Dry the residuum, and digest it in five times its weight of rectified petroleum. Express the liquid part by squeezing the substance in a linen cloth. Let this liquid remain several days to settle, then decant off the clear liquid part, mix it with a third part of water and distil; the caoutchouc remains behind *.

According to Bucholz, opium contains a considerable portion of caoutchouc †. That part of mastich which is insoluble in alcohol possesses the properties of caoutchouc, as has been formerly observed.

SECT. XXVII.

OF GUM RESINS.

This class of vegetable substances has been long distinguished by physicians and apothecaries. It contains many active substances much employed in medicine; and they certainly possess a sufficient number of peculiar properties to entitle them to be ranked apart. Unfortunately these substances have not yet attracted much of the attention of chemists. Their properties and constituents of course are but imperfectly ascertained. Of

* Hermbstadt, *Med. and Phys. Jour.* iii. 372.
† *Ann. de Chim.* xxxiv. 133.

Book IV. late, however, they have engaged the attention of M. Braconnet, who has recently published a very detailed examination of several of them, and has promised to examine in the same manner the whole of the class *. They may, however, be distinguished by the following characters.

Properties. They are usually opaque, or at least their transparency is inferior to that of the resins. They are always solid, and most commonly brittle, and have sometimes a fatty appearance.

When heated they do not melt as the resins do; neither are they so combustible. Heat, however, commonly softens them, and causes them to swell. They burn with a flame.

They have almost always a strong smell, which in several instances is alliaceous. Their taste also is often acrid, and always much stronger than that of the resins.

They are partially soluble in water; but the solution is always opaque, and usually milky.

Alcohol dissolves only a portion of them. The solution is transparent; but when diluted with water it becomes milky; yet no precipitate falls, nor is any thing obtained by filtering the solution.

Vinegar and wine likewise dissolve them partially; and the solution, like the aqueous, is opaque or milky.

According to Hermbstadt, they are insoluble in sulphuric ether.

The action of alkalies on them has been examined only by Mr Hatchett. All of them tried by that cele

* *Ann. de Chim.* lxviii. 19.

brated chemist dissolved readily in alkaline solutions when assisted by heat. We may therefore consider them as soluble in alkalies like resins. Chap. I.

From the experiments of Mr Hatchett, we learn that the acids act on these bodies nearly as they do on the resins. Sulphuric acid dissolves them, and gradually converts them into artificial tannin and charcoal. The following are the quantities of charcoal obtained by this celebrated chemist from 100 grains of different gum resins digested in alcohol:

Ammoniac............58	Myrrh............40
Asafœtida.............51	Gamboge........31
Olibanum.............44	

Nitric acid acts upon them with energy; converting them first into a brittle mass, and then, with the assistance of heat, dissolving them. By evaporating this solution, Mr Hatchett obtained, from ammoniac and asafœtida, a portion of artificial tannin; but he did not succeed in procuring it by the same means from olibanum, myrrh, and gamboge *.

Their specific gravity is usually greater than that of the resins.

Their other properties still continue unknown. They all either exude spontaneously from plants, or are obtained by incisions. At first they seem to be in a liquid state; but they gradually harden when exposed to the air and weather.

They have been usually considered by chemists as composed of gum and resin; but their properties are not consistent with that supposition. They all contain

* *Phil. Trans.* 1806.

Book IV. a volatile oil, or a substance intermediate between an oil and resin. To this substance we are to ascribe the milky solution which they form with water. The other constituent, in most cases, bears a much closer resemblance to extractive than to gum. Perhaps, then, we will not err very far, if we consider the gum resins as composed of a gum or an extractive substance, and a body intermediate between oil and resin; to which last they owe their most peculiar properties.

The gum resins which have been hitherto applied to any useful purpose are the following:

Galbanum. 1. *Galbanum*. It is obtained from the *bubon galbanum*, a perennial plant, and a native of Africa. When this plant is cut across a little above the root, a milky juice flows out, which soon hardens and constitutes galbanum. It comes to this country from the Levant, in small pieces composed of tears, agglutinated together, of a yellowish or white colour. Its taste is acrid and bitter, and its smell peculiar. Water, vinegar, and wine, dissolve part of it, but the solution is milky. Alcohol dissolves about $\frac{1}{5}$ths. When distilled it yields about half its weight of volatile oil, which has at first a blue colour. Its specific gravity is 1·212 *.

Ammoniac. 2. *Ammoniac*.—This substance is brought from the East Indies. Nothing certain is known concerning the plant which yields it; though from analogy it has been suspected to be a species of *ferula* †. It is in small pie-

* Brisson.

† Wildenow made the seeds vegetate which are observed in ammoniac. Of the plant produced he has formed a new genus under the name of *heracleum gummifera*. But as the roots of this plant were not observed to yield *ammoniac*, it is still doubtful how far it is the plant from which ammoniac is procured. See *Ann. de Chim*. lxix. 267.

ces agglutinated together, and has a yellowish white colour. Its smell is somewhat like that of galbanum, but more pleasant. Its taste is a nauseous sweet mixed with bitter. It does not melt. Water dissolves a portion of it; the solution is milky, but gradually lets fall a resinous portion. More than one-half is soluble in alcohol. This portion is a resin. Colour white, soft, and ductile. Melts when heated, and burns like a resin. When heated becomes harder, but not brittle. Nearly tasteless. Soluble in ether and in nitric acid. Precipitated from it in the form of an orange substance, partly resin, partly bitter. A portion remains, and gives the liquid a yellow colour. Taste of the solution slightly acid and bitter. Not precipitated by carbonate of soda, ammonia, nitrate of silver, nor acetate of lead. The orange substance has a bitter taste. When heated, readily swells and blackens, but does not flame. Burns without leaving any residuum. Lighter than water. When agitated in water, tinges it yellow, but does not all dissolve. The specific gravity of ammoniac is 1·207. Mr Hatchett found it soluble in alkalies. Neither alcohol nor water, when distilled off it, bring over any thing.

According to the analysis of Braconnot ammoniac is composed of the following ingredients:

70·0	resin
18·4	gum
4·4	glutinous matter
6·0	water
1·2	loss
100·0	

The resin he found brittle and yellow. In these respects

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it differs from the resin which I extracted from ammoniac, which was soft, and continued so after being exposed to the air for two months. This difference is probably owing to the state of the ammoniac, sometimes it is brittle and yellow, at other times soft and white. It was in this last state that I examined it. Braconnot found the yellow matter into which this resin is converted by nitric acid soluble in hot alcohol and water. It had the property of dyeing silk a fine yellow colour, not altered by oxymuriatic acid. The gum which he extracted from ammoniac possessed the properties of common gum as far as he examined them. It is transparent, yellowish, brittle, soluble in water, and precipitated by acetate of lead, but not by the superacetate nor the nitrate of lead. The mercurial salts render the solution milky. By nitric acid it is converted into saclactic and oxalic acids, and furnishes also a little malic acid. The glutinous matter was insoluble in water and alcohol; it became black when dried, and yielded yellow matter and some oxalic acid when treated with nitric acid*.

Olibanum.

3. *Olibanum.*—This substance is obtained from the *juniperus lycia*, and is chiefly collected in Arabia. It is the frankincense of the ancients. It is in transparent brittle masses about the size of a chesnut. Its colour is yellow. It has a bitterish nauseous taste, and when burnt diffuses an agreeable odour. Alcohol dissolves ¾ths of it; and water about ⅜ths. When distilled it yields a little volatile oil; but gives no

* *Ann. de Chim.* lxviii. 69.

either with water or alcohol *. Its specific gravity is 1·173 †. Chap. I.

4. *Sagapenum*.—The plant which yields this gum resin is not well known; but it is suspected to be the *ferula persica*. The substance itself is brought to Europe from Alexandria. It is commonly in tears agglutinated together. Colour yellow. Taste hot and bitter. Smell alliaceous. Softens between the fingers, but does not melt when heated. Sparingly soluble in water, but almost completely soluble in alcohol. When distilled with water it yields a little volatile oil. The water is strongly impregnated with the flavour of the sagapenum ‡. Sagapenum.

5. *Asafœtida*.—This substance is obtained from the *ferula asafœtida*, a perennial plant which is a native of Persia. When the plant is about four years old, its roots are dug up and cleaned. Their extremity being then cut off, a milky juice exudes, which is collected. Then another portion is cut off, and more juice exudes. This is continued till the roots are exhausted. The juice thus collected soon hardens and constitutes *asafœtida*. It comes to Europe in small grains of different colours, whitish, reddish, violet, brown. Pretty hard, but brittle. Its taste is acrid and bitter; its smell strongly alliaceous and fetid. Alcohol, according to Neumann, dissolves about $\frac{3}{4}$ths of this substance; and water takes up nearly $\frac{1}{4}$th if applied before the spirit. A considerable portion of earthy matter remains undissolved. It yields a volatile oil, both when distilled Asafœtida.

* Neumann's *Chem.* p. 315.

† Brisson.

‡ Neumann's *Chem.* p. 316.

Book IV. with water and alcohol. This oil possesses the ac properties of the asafœtida itself *. The specific gr ty of the gum resin is 1·327.

Scammony. 6. *Scammony*.—This substance is obtained from *convolvulus scammonia*, a climbing plant which gı in Syria, and was first correctly described by Dr I sel †. The roots when cut yield a milky juice. ' when collected and allowed to harden constitutes s‹ mony. Colour dark grey or black. Smell pecı and nauseous: taste bitter and acrid. With wat forms a greenish-coloured opaque liquid. Alcohol solves the greatest part of it. It is usually mixed the expressed juice of the root, and frequently also other impurities, which alter its appearance. In m cine it operates as a strong cathartic. Its specific vity is 1·235 ‡.

Opoponax. 7. *Opoponax*.—This substance is obtained from *pastinaca opoponax*, a plant which is a native of countries round the Levant. The gum resin, like others, is obtained by wounding the roots of the p The milky juice, when dried in the sun, constitutes opoponax. It is in lumps of a reddish yellow co and white within. Smell peculiar. Taste bitter acrid. With water it forms a milky solution, about one-half of it dissolves. Alcohol acts but fee When distilled with water or alcohol, these liquid quire the flavour of opoponax, but no oil separat Its specific gravity is 1·622 ‖.

* Neumann's *Chemistry*, p. 312.

† See an abridgment of his account by Dr Lewis, Neumann's p. 303. ‡ Brisson. § Neumann's *Chem*. p. 316.

‖ Brisson.

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Gamboge.

8. *Gamboge* or *Gumgutt*.—This substance is obtained from the *stalagmitis gambogioides*, a tree which grows wild in the East Indies. In Siam it is obtained in drops by wounding the shoots; in Ceylon it exudes from wounds in the bark. It is brought to Europe in large cakes. Its colour is yellow; it is opaque, brittle, and breaks vitreous. It has no smell, and very little taste. With water it forms a yellow turbid liquid. Alcohol dissolves it almost completely; and when mixed with water becomes turbid, unless the solution contain ammonia. In that case acids throw down an insoluble yellow precipitate. It operates, when taken internally, as a most violent cathartic. Its specific gravity is 1·221 *. It appears that it was brought to Europe by the Dutch about the middle of the 17th century †. It forms a fine yellow paint, and stains hot marble of a fine lemon yellow ‡.

Braconnet analysed, it and found it composed of one part of a gum which possessed the properties of cherry tree gum, and four parts of a reddish brittle resin which possessed the characteristic properties of the resins. It dissolved in alcohol and alkalies, and by nitric acid was converted into a yellowish bitter matter. Oxymuriatic acid deprived it of its dark colour, and a combination took place between it and muriatic acid, in which it neutralized that acid §.

9. *Myrrh*.—The plant from which this substance is obtained is unknown. If we believe Bruce it belongs Myrrh.

* Brisson.

† See the *Anatomia Essentiarum Vegetabilium* of Angelus Sala, p. 31.

‡ Lewis, Neumann's *Chem.* p. 300.

§ *Ann. de Chim.* lxviii. 33.

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to the genus of *mimosa*. It grows in Abyssinia and Arabia. It is in the form of tears. Colour reddish yellow; when pure somewhat transparent, but it is often opaque. Odour peculiar. Taste bitter and aromatic. Does not melt when heated, and burns with difficulty. With water it forms a yellow opaque solution. The solution in alcohol becomes opaque when mixed with water, but no precipitate appears. By distillation with water it yields an oil heavier than water; but nothing comes over with alcohol *. Its specific gravity is 1·360 †. It is employed in medicine. Mr Hatchett found it soluble in alkalies.

From the analysis of Braconnot it appears that myrrh is composed of about

23	resin
77	gum
100	

The resin is reddish, has a bitter taste and the peculiar odour of myrrh. The gum differs in its properties from every other gummy substance hitherto examined. It has a dark brown colour; is at first soluble in water, but by boiling the liquid, or by exposing the gum to heat, it acquires cohesive properties, and becomes insoluble in water. When distilled it yields ammonia, and when dissolved in nitric acid azotic gas is disengaged. These properties show an analogy between it and animal substances. It is precipitated by the salts of lead, mercury, and tin, and it falls in combination with the oxides of these metals ‡.

* Lewis, Neumann's *Chem*. p. 317. † Brisson.
‡ *Ann. de Chim*. lxviii. 52.

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Euphorbium.

10. *Euphorbium.*—This substance is obtained from the *euphorbia officinalis*. The milky juice which exudes from that plant, when dried in the sun, constitutes euphorbium. It is brought from Africa in small yellow tears. It has no smell, and is mostly soluble in alcohol. Its specific gravity is 1·124 ¶. It is considered as poisonous.

According to the analysis of Braconnot it is composed of

37·0	resin
19·0	wax
20·5	malate of lime
2·0	Malate of potash
5·0	Water
13·5	Woody matter
3.0	Loss
100·0	

The resin has peculiar properties. It is reddish and transparent, excessively acrid, and possesses poisonous properties. It is insoluble in alkalies, but soluble in sulphuric and nitric acids. These properties show it to be a peculiar vegetable principle. The wax possesses the properties of bees wax. The malate of lime had been mistaken for gum †.

11. Little is known concerning the substances called *bdellium* and *caranna*, reckoned among the gum resins. The specific gravity of the first is 1·371, of the second 1·124 ‡. Bdellium was celebrated by the ancient physicians. It comes from Arabia. The substance ex-

¶ Brisson. † *Ann. de Chim.* lxviii. 44. ‡ Brisson.

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tracted from ivy, and known by the name of *gummi hederæ*, is considered at present as a gum resin; but I do not know that it has been chemically examined. Its specific gravity is 1·294.

12. From the experiments made upon ipecacuan, the root of the *cephelis ipecacuanha*, especially by Dr Irvine, we learn that it also contains a gum resin. The same remark applies to several other vegetable substances employed in medicine.

It deserves attention, that the gum resins, when subjected to destructive distillation, yield all of them a portion of ammonia; a proof that they all contain azote. In this respect they agree with gum and extractive.

SECT. XXVIII.

OF COTTON.

Cotton is a soft down which envelopes the seeds of various plants, especially the different species of *gossypium*, from which the cotton of commerce is procured.

Origin.

These plants are natives of warm climates; grow wild in Asia, Africa, and America, within the tropics; and are cultivated in the East and West Indies. The finest cotton, according to Mr Edwards, is distinguished by the name of *green seed cotton*, from the colour of its seeds *, and is perhaps the produce of the *gossy-*

* *History of the West Indies*, ii. 264.

pium hirsutum. There are two species of it; in one of which the cotton does not easily part from the seeds. But the cotton plant commonly cultivated is a shrub, of which Mr Edwards enumerates five kinds; namely, the *common Jamaica*, the *brown bearded*, the *nankeen*, the *French* (*gossypium arboreum*), and the *kidney cotton**. When the seeds are ripe, the pods open, and display the cotton, which is collected and separated from the seeds by means of rollers.

Cotton, when spun and woven into cloth, furnishes garments to a very considerable portion of the civilized world. The quantity annually brought into this country, and spun by machinery, is not less than 20 millions of pounds; and the number of individuals employed in manufacturing it cannot be less than 100,000. It constitutes therefore one of the most important of our manufactures.

Though no correct chemical investigation of the properties of cotton has hitherto been made, yet as its obvious qualities distinguish it sufficiently from every other vegetable substance, we must consider it as a peculiar vegetable principle; and I have introduced it here, in hopes that some person or other will be induced to examine its nature in detail. The following are the particulars at present known.

Properties.

This substance is in threads differing in length and in fineness. No asperities can be discovered on the surface of these threads; but if Lewenhoeck's microscopical observations are to be trusted, they are all tri-

* Perhaps the first species are only varieties of the *gossypium herbaceum*.

Book IV. angular, and have three sharp edges. Cotton di considerably in colour; but when bleached it beco of a fine white.

Cotton is tasteless and destitute of smell. It is c pletely insoluble in water, alcohol, ether, and oils, in all the vegetable acids.

The diluted alkaline leys have no perceptible ac on cotton; but when very strong they dissolve it i sisted by a sufficient degree of heat. The new ducts obtained by this solution have not been exa ned.

Cotton has a strong affinity for some of the ea especially for alumina. Hence this substance is to fix colours on cotton. The cloth is steeped in a lutiom of alum or acetate of alumina, and afterw dyed.

Several of the metallic oxides also combine wi readily, and remain united with much obstinacy. ide of iron is one of the most remarkable. When ton is dipt into a solution of iron in an acid, it co out yellow, and the iron is neither separated by a lies nor soap, nor even by acids, unless when the c bination is quite recent. The colour gradually d ens by exposure to the air, owing no doubt to the idizement of the iron, unless the cloth be steeped in aluminous solution, which prevents the colour from coming disagreeable, probably by diluting it *. O of tin also combines with cotton, and is frequently as a mordant.

Cotton combines readily with tannin, and form

* See Chaptal, *Ann. de Chim.* xxvi. 266.

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yellow or brown compound. Hence the infusion galls, and of other astringent substances, is often used as a mordant for cotton.

Nitric acid decomposes cotton when assisted with heat, and oxalic acid is formed; the other products have not been examined. Sulphuric acid likewise chars it. Oxymuriatic acid gas bleaches it, and probably alters and dissolves it when applied in a concentrated state.

Cotton is extremely combustible, and burns with a clear lively flame. The ashes left behind, according to Neumann, contain some potash. When distilled it yields a great portion of acidulous water, and a small quantity of oil, but no ammonia *.

SECT. XXIX.

OF SUBER.

This name has been introduced into chemistry by Fourcroy, to denote the outer bark of the *quercus suber*, or the common cork; a substance which possesses properties different from all other vegetable bodies.

It is exceedingly light, soft, and elastic; very combustible, burning with a bright white flame, and leaving a light black bulky charcoal; and when distilled, yields a little ammonia.

* Neumann's *Chem.* p. 430.

Book IV. Properties.

When digested in water, a yellowish-coloured soli tion is obtained, seemingly containing extractive, nearly the same proportion is taken up by alcohol Sulphuric acid readily chars it. Nitric acid gives it yellow colour, corrodes, dissolves, and decomposes it converting it partly into suberic acid, partly into a sul stance resembling wax, partly into artificial tannin, ar partly into a kind of starchy matter †.

Fourcroy supposes, from some experiments which l does not relate, that the epidermis of all trees is a sul stance possessed of the same properties with cork; an perhaps we may conclude from the experiments of Linl that all vegetable membrane possesses nearly the san chemical characters. At least it agrees with cor in furnishing suberic acid when treated with nitr acid ‡.

SECT. XXX.

OF WOOD.

All trees, and most other plants, contain a particul substance, well known by the name of *wood*. If a pie

* Neumann's *Chemistry*, p. 428.

† Bouillon La Grange, *Ann. de Chim.* xxiii. 50.

‡ Nicholson's *Jour.* xxiii. 155.

of wood be well dried, and digested, first in a sufficient quantity of water and then of alcohol, to extract from it all the substances soluble in these liquids, there remains only behind the *woody fibre*. Chap. I.

This substance, which constitutes the basis of wood, is composed of longitudinal fibres, easily subdivided into a number of smaller fibres. It is somewhat transparent; is perfectly tasteless; has no smell; and is not altered by exposure to the atmosphere.

Properties.

It is insoluble in water and in alcohol. The fixed alkalies, when assisted by heat, give it a deep brown colour, render it soft, and decompose it. A weak alkaline solution dissolve it without alteration; and it may be thrown down again by means of an acid. By this property we are enabled to separate wood from most of the other vegetable principles, as few of them are soluble in weak alkaline leys.

Action of heat,

When heated, it blackens without melting or frothing up, and exhales a disagreeable acrid fume, and leaves a charcoal which retains exactly the form of the original mass. When distilled in a retort, it yields an acid liquor of a peculiar taste and smell, distinguished by the name of pyrolignous, and formerly considered as a distinct acid; but Fourcroy and Vauquelin have lately ascertained that it is merely the acetic acid combined with an empyreumatic oil *.

* Mollerat is said to have succeeded in France in making acetic acid from wood as pure as radical vinegar. It answers very well for aromatic vinegar, but possesses a little acrimony, which makes it less fit for the table. See Nicholson's *Jour*. xxiv. 70.

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Of nitric acid.

By nitric acid Fourcroy converted the residuum of quinquina, which does not seem to differ from the woody fibre, into oxalic acid; at the same time there was a little citric acid formed, and a very small quantity of malic and acetic acids. Some azotic gas also was disengaged.

By this process he obtained from 100 parts of woody fibre

56·250	oxalic acid
3·905	citric acid
0·388	malic acid
0·486	acetic acid
0·867	azotic gas
8·330	carbonate of lime
70·226	
32·031	residuum
102·257	

There was likewise a quantity of carbonic acid gas disengaged, the weight of which was unknown. This increase of weight in the product was evidently owing to the oxygen derived from the nitric acid *.

When this residuum was distilled in a retort, 100 parts yielded the following products:

* *Ann. de Chim.* viii. 153.

Chap. I.

20 of a yellow liquid, containing alcohol, and an acid which had the smell of pyromucous.
77 of concrete oil, mostly soluble in alcohol
95 charcoal } in the retort
67 carbonate of lime }
—
59
41 gas, half carbonic acid, half carbureted hydrogen
—
00 *

en wood is burnt with a smothered flame, it leaves well known, a quantity of charcoal behind it, exhibits the exact form, and even the different of the original wood. As it is the *wood* alone undergoes this change, while the other compo- arts of the plant are dissipated, we may form notion of the relative proportion of wood which nt plants contain, by the proportion of charcoal they yield. Now, the quantity of charcoal yield- 1·00 of different trees is, according to the ex- ents of Proust, as follows:

Black ash	0·25
Guaiacum	0·24
Pine	0·20
Green oak	0·20
Heart of oak	0·19
Wild ash	0·17
White ash	0·17

Composition.

om the facts above related, it appears that the of plants is composed of oxygen, carbon, hydro-

* *Ann. de Chim.* viii. 151.

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gen, azote, and lime. Mr Chaptal supposes that mucilage differs from woody fibre merely in containing less oxygen. We are certain at least that mucilage or gum is composed of the same ingredients; and Mr Chaptal has shown, that the juices of plants are partly converted into a substance similar to woody fibre by oxymuriatic acid, which imparts to them oxygen *. These juices contain both gum and resin: after the formation of the woody fibre the resin is still unaltered. This gives some probability to his opinion, provided it can be proved that extractive, by combining with oxygen, assumes the properties of wood; for the precipitate observed by Chaptal was undoubtedly extractive.

SECT. XXXI.

OF ALKALIES.

THE only alkalies found in plants are potash and soda. Ammonia may indeed be obtained by distilling many vegetable substances, but it is produced during the operation. One or other of these alkalies is found in every plant which has hitherto been examined. The quantity indeed is usually very small. From the experiments of Vauquelin, it is probable that the alkalies are combined in plants with acetic and carbonic acids.

* *Ann. de Chim.* xxi. 285.

Chap. I.
Potash.

Potash is found in almost all plants which grow at tance from the sea. It may be extracted by burn- he vegetable, washing the ashes in water, filtrating vater, and evaporating it to dryness. It is in this er that all the potash of commerce is procured.

e following Table exhibits the quantity of ashes otash which may be extracted from 100 parts of us plants :

llow........................	2·8	0·285 *
m..........................	2·36727	0·39 †
k..........................	1·35185	0·15343
plar........................	1·23476	0·07481
rnbeam	1·1283	0·1254
ech........................	0·58432	0·14572
r..........................	0·34133	
ne branches............	3·379	0·55 †
ommon nettle.........	10·67186	2·5033

hose marked † are from Kirwan, *Irish Trans.* v. 164. The rest Pertuis, *Ann. de Chim.* xix. 178. The following Table, by Redi, of es and salts yielded by different plants, is worth inserting. It is d in the *Phil. Trans.* for 1698 (vol. xx. p. 281.)

nds.	Vegetables.	Ashes lbs.	oz.	dr.	Salts. oz.	dr.
o	Of dried flowers of oranges -	4	6	0	0	5
o	Of gourds new gathered, which dried in the oven were 36 lbs -	4	0	0	10	0
o	Red onions (being 720) roasted, the coals turned to 16 lbs to the coals new added 4 oz. of sulphur -	1	6	0	2	2
o	Eyebright fresh, and afterwards stilled and burnt - -	5	0	0	4	0
o	Distilled roses - -	4	0	1	0	0
o	Of maidenhair - -	9	0	0	0	4
o	Roots of black hellebore, which dried came to 50 lbs. -	6	0	0	1	0
o	Roots of white hellebore, fresh, which dried came to 50 lbs. -	2	0	0	4	0

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Common thistle	4·04265	0·53734
Fern	5·00781	0·6259
Cow thistle	10·5	1·96603
Great river rush	3·85395	0·72234
Feathered rush	4·33593	0·50811
Stalks of turkey wheat.	8·86	1·75 †
Wormwood................	0·744	7·3
Fumitory..................	21·9	7·9 †
Trifolium pratense..........................		0·078 †
Vetches..		2·75 †
Beans with their stalks..................		2·0 †

Pounds.	Vegetables.	Ashes. lbs.	oz.	dr.	Salts. oz.	dr.
96	Roots dried and burnt of fresh esula	3	0	0	2	
30	Roots of liquorice - -	2	0	0	1	4
20	Pellitory - -	1	0		0	6
100	Green endive - -	2	0	0	2	0
90	Green bindweed -	1	0	0	2	
2500	Leaves of laurel - -	33	0	4	0	0
500	Leaves of laurel -	6	0	0	10	
1000	Water melons well ripe, the seeds being taken - -	25	0	1	9	
2400	Cucumbers - -	18	0	0	0	
300	Wood of ivy - -	9	0	0	0	
50	Scorzonera dried -	8	0	0	0	
300	Pine apples, the nuts taken out -	3	0	0	0	
150	Mugwort dried - -	8	0	0	0	
130	Leaves of cyprus - -	6	0	0	0	
10	Peel of pomegranates dried -	0	8	0	0	
2	Sassafras - - -	0	0	0	0	
12	Lignum sanctum - -	2	6	0	0	
4	Yellow sanders -	0	1	4	0	
4	Black pepper - -	0	2	4	0	
30	Ginger - -	1	7	0	0	
12	Turbith - -	1	0	0	[illegible]	[illegible]
	Wood of fir - -	3	0	[illegible]	[illegible]	[illegible]
	Scopæ - - -	[illegible]				
	Scopæ - - -	16				

Chap. I.

In general, three times as much ashes are obtained from shrubs, and five times as much from herbs, as from trees. Equal weights of the branches of trees produce more ashes than the trunk, and the leaves more than the branches. Herbs arrived at maturity produce more ashes than at any other time. Green vegetables produce more ashes than dry *.

The salt which is obtained from plants does not consist wholly of potash, there are other salts mixed with it; these usually are sulphate of potash, muriate of potash, sulphate of lime, phosphate of lime, &c.; but these bear, in general, but a small proportion to the potash. The ashes consist of potash mixed with earths.

Some judgment may be formed of the quantity of potash which a plant contains, from the quantity of ashes which it yields: but the above Table is sufficient to show us, that were we to trust to that we would often be misled.

Soda.

2. Soda is found in almost all the plants which grow in the sea, and in many of those which grow on the shore. In general, the quantity of soda which plants contain bears a much greater proportion to their weight than the potash does which is found in inland vegetables. 100 parts of the *salsola soda*, for instance, yield 19·921 of ashes; and these contain 1·992 parts of soda; some of which, however, is combined with muriatic acid †. The plants from which the greater part of the soda, or *barilla* as it is called, which is imported from Spain, is extracted, are the *salsola sativa* and *vermiculata*.

* Ann. de Chim.

† Vauquelin, Ibid. xviii. 77.

SECT. XXXII.

OF EARTHS.

The only earths hitherto found in plants are the fou following; *lime, silica, magnesia, alumina.*

Lime. 1. Lime is usually the most abundant of the earth of plants, and the most generally diffused over the veg table kingdom. Indeed it is a very uncommon thin to find a plant entirely destitute of lime: salsola soda almost the only one in which we know for certain th this earth does not exist *.

Silica. 2. Silica exists also in many plants, particularly i grasses and equisetums. Mr Davy has ascertained th it forms a part of the epidermis, or outermost bark these plants; and that in some of them almost the who epidermis is silica.

	Parts Silica.
100 parts of the epid. of bonnet cane yielded	90
bamboo..........	71·4
(arundo phragm.) common reed	48·1
stalks of corn......	6·5

The concretions which are sometimes found in th

* Vauquelin, *Ann. de Chim.* xviii. 76.

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cane called tabasheer, have been ascertained Macie to be composed of pure silica ‡.

Magnesia.

lagnesia does not exist so generally in the vege-ingdom as the two preceding earths. It has been however, in considerable quantities in several ats, especially fuci **; but the salsola soda con-greater proportion of magnesia than any plant examined. Mr Vauquelin found that 100 f it contained 17·929 of that earth ¶.

Alumina.

lumina has only been found in very small quan-plants.

following Table will show the quantity of these rths which exist in several vegetables.

parts of oak contains of earths	1·03 ‖
Beech	0·453 †
Fir	0·003 †
Turkey wheat	7·11 †
Sunflower	3·72 †
Vine branches	2·85 †
Box	2·674 †
Willow	2·515 †
Elm	1·96 †
Aspin	1·146 †
Fern	3·221 *
Wormwood	2·444 §
Fumitory	14·000 §

urcroy and Vauquelin lately examined a tabasheer from the Andes, d it composed of 70 silica and 30 potash. Gehlen's *Jour*. Second ii. 112.

Vauquelin, *Ann. de Chim*. xviii. 86. and ix. 94. ¶ Ibid. p. 78.

Watson. † Kirwan, *Irish Trans*. iii. 35.

Home. § Wiegleb.

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This Table shows us that the quantity of eart greater in herbs than in trees.

Bergman found all the four earths in every kin grain which he analysed *.

Vauquelin found that 100 parts of oat grain 3·1591 of residuum. This residuum is composed c

60·7 silica
39·3 phosphate of lime

100·0 †

When the whole of the *avena sativa*, however, st and seed together, is burnt, it leaves a residuum co posed of..........55 silica
15 phosphate of lime
20 potash
5 carbonate of lime

95 and a little oxide of iron ‡

This shows us that the stalk contains several s stances not to be found in the grain.

The following Table exhibits the quantity of ea and metallic oxides in grains, obtained by Schra from 32 ounces of the seeds of the following kind corn; wheat (*triticum hybernum*), rye (*secale cerea* barley (*hordeum vulgare*), oats (*avena sativa*), likewise from the same quantity of rye straw §.

* *Opusc.* v. 94.
† *Ann. de Chim.* xxix. 17.
‡ Ibid. 19.
§ Gehlen's *Jour.* iii. 525.

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Earths in corn.

	Wheat.	Rye.	Barley.	Oats.	Rye Straw.
a	13·2	15·6	66·7	144·2	152
bonate of lime	12·6	13·4	24·8	33·75	46·2
bonate of magnesia	13·4	14·2	25·3	33·9	28·2
mina	0·6	1·4	4·2	4·5	3·2
de of manganese	5·0	3·2	6·7	6·95	6·8
de of iron	2·5	0·9	3·8	4·5	2·4
	47·3	48·7	131·5	227·8	238·8

aussure junior, in his *Chemical Researches on Vege-on*, a work published in 1804, has given us the most ious table of the earthy and saline constituents of etables which has yet appeared. This table is the e valuable, as it was constructed entirely from his experiments. For that reason I shall insert it in place:

Saussure's table.

ABLE OF INCINERATIONS.				Constituents of 100 parts of the Ashes.					
Names of plants.	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
eaves of oak (*quercus robur*) May 10.	13	53	745	47	24	0·12	3	0·64	15·24
Ditto, Sept. 27.	24	55	549	17	18·25	23	4·5	1·75	25·5
Wood of a young oak, May 10.		4		26	28·5	12·25	0·12	1	12·58
Bark of ditto		60		7	4·5	63·25	0·25	1·75	12·75

TABLE continued.

	Table of Incinerations.				Constit. of 100 parts of the ashes.					
	Names of plants.	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
5	Perfect wood of oak.		2		38·6	4·5	32	2	2·25	20·[illegible]
6	Alburnum of do.				32	24	11	7·5	2	23·[illegible]
7	Bark of ditto.		60		7	3	66	1·5	2	21·[illegible]
8	Cortical layers of ditto.		73		7	3·75	65	0·5	1	12·[illegible]
9	Extract of wood of ditto.		61		51					
10	Soil from wood of ditto.		41		24	10·5	10	32	14	8·[illegible]
11	Extract from do.		111		66					
12	Leaves of poplar (*populus nigra*), May 26.	23	66	652	36	13	29	5	1·25	15·[illegible]
13	Ditto Sept. 12.	41	93	565	26	7	36	11·5	1·5	18
14	Wood of ditto, Sept. 12.		8	26		16·75	27	3·3	1·5	24·[illegible]
15	Bark of ditto.		72		6	5·3	60	4	1·5	23·[illegible]
16	Leaves of hazel (*corylus avellana*), May 1.		61		26	23·3	22	2·5	1·5	24·7
17	Ditto washed in cold water.		57		8·2	19·5	44·1	4	2	22·[illegible]
18	Leaves of ditto, June 22.	28	62	655	22·7	14	29	11·3	1·5	21·5

TABLE continued.

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…of Incinerations.				Constit. of 100 parts of the ashes.					
	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
…pt. 20.	31	70	557	11	12	36	22	2	17
…f ditto. …		5		24·5	35	8	0·25	0·12	32·2
…ditto.		62		12·5	5·5	54	0·25	1·75	26
…wood of …ry (*…re*), N… …r.		7		21	2·25	56	0·12	0·25	20·38
…n of dit-		13		26	17·25	24	1	0·25	21·5
…itto.		89		7	8·5	15	15·25	1·12	13·13
…layers of		88		10	16·5	48	0·12	1	24·38
…wood of …am (*car-* *betulus*),	4	6	346	22	23	26	0·12	2·25	26·63
…n of do.	4	7	390	18	36	15	11	1	29
…itto.	88	134	346	4·5	4·5	59	1·5	0·12	30·38
…f horse …t (*escu-* …*ppocasta-* …May 10.		35		9·5					
…of dito, …o.	16	72	782	50					
…ly 23	29	54	652	24					
…pt. 27.	31	86	636	13·5					

TABLE continued.

	Table of Incinerations.				Constit. of 100 parts of the ashes.					
	Names of plants.	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
33	Flowers of ditto. May 10.	9	[illegible]1	873	50					
34	Fruit of ditto, October 5.	12	54	647	82	12	0	0·5	0·25	5·25
35	Plants of pease (*pisum sativum*), in flower.		95		49·8	17·25	6	2·3	1	24·65
36	Ditto ripe,		81		34·25	22	14	11	2·5	17·25
37	Plants of vetches (*vicia faba*), before flowering, May 23.	16	150	895	55·5	14·5	3·5	1·5	0·5	24·50
38	Ditto in flower, June 23.	20	122	876	55·5	13·5	4·12	1·5	0·5	24·38
39	Ditto ripe, July 23.		66		[illegible]0	17·75	4	1·75	0·5	26
40	Ditto, seeds separated.		115		42	5·75	36	1·75	1	12·9
41	Seeds of ditto.		33		69·28	27·92	0	0	0·5	2·3
42	Ditto in flower, raised in distilled water.		39		60·1	30	0	0	0·5	9·4
43	*Solydago vulgaris*, before flowering, May 1		92		67·5	10·75	1·5	1·5	0·75	18·25
44	Ditto just in flower, July 15.		57		59	59	1·5	1·5	0·75	2[illegible]

TABLE continued.

...able of Incinerations.				Constit. of 100 parts of the ashes.					
Names of plants.	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
...to Seeds ripe, Sept 20.		50		48	11	17·25	3·5	1·5	18·75
...nts of turnsol (*helianthus annuus*), a month before flowering, June 23.		147		63	6·7	11·56	1·5	0·12	16·67
...to in flower, July 23.	13	137	877	61	6	12·5	1·5	0·12	18·78
...to bearing ripe ...ds, Sept. 20.	23	93	753	51·5	22·5	4	3·75	0·5	17·75
...heat (*triticum aestivum*) in flower.				43·25	12·75	0·25	32	0·5	12·25
...to seeds ripe.				11	15	0·25	54	1	18·75
...tto a month before flowering		79		60	11·5	0·25	12·5	0·25	15·5
...tto in flower, June 14.	16	54	699	41	10·75	0·25	26	0·5	21·5
...tto seeds ripe.		33		10	11·75	0·25	51	0·75	23
...raw of wheat.		43		22·5	6·2	1	61·5	1	7·8
...eds of ditto.		13		47·16	44·5	0	0·5	0·25	7·6
...ran.		52		4[illegible]·16	46·5	0	0·5	0·25	8·6
...lants of maize (*zea mays*), a month before flowering, June 23.		122		[illegible]	[illegible]·75	0·25	7·5	0·25	17·25

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TABLE *continued*.

Table of Incinerations.					Constit. of 100 parts of the Ashe[s]					
	Names of plants.	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
58	Ditto in flower, July 23.		81		69	6	0·25	7·5	0·25	17
59	Ditto seeds ripe		46							
60	Stalks of ditto.		84		72·45	5	1	18	0·5	3[illegible]
61	Spikes of ditto.		16							
62	Seeds of ditto.		10		62	36	0	1	0·12	0[illegible]
63	Chaff of barley (*hordeum vulgare*).		42		20	7·75	12·5	57	0·5	2[illegible]
64	Seeds of ditto.		18		29	32·5	0	35·5	0·25	2[illegible]
65	Ditto.				22	22	0	21	0·12	29[illegible]
66	Oats.		31		1	24	0	60	0·25	14·[illegible]
67	Leaves of *rhododendron ferrugineum*, raised on Jura, a limestone hill, June 20.		30		23	14	43·25	0·75	3·25	15·[illegible]
68	Ditto raised on Breven, a granite hill, June 27.		25		21·1	16·75	16·75	2	5·75	31·5
69	Branches of ditto, June 20.		8		22·5	10	39	0·5	5·4	22·[illegible]
70	Spikes of ditto, June 27.		8		24	11·5	29	1	11	24·5

TABLE continued.

…BLE OF INCINERATIONS.				Constit. of 100 parts of the ashes.					
Names of plants.	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
…es of fir (*pi-* … *abies*) rai- … on Jura, …ne 20.		29		16	12·27	43·5	2·5	1·6	24·13
… raised on …rven, June		29		15	12	29	19	5·5	19·5
…ches of pine, …e 20.		15		15					
…erry (*vacci-* … *m myrtillus*), …ed on Jura, …g. 29.		26		17	18	42	0·5	3·12	19·38
…, raised on …en, Aug. 20		22		24	22	22	5	9·5	17·5
…from *rhodo-* …*dron ferru-* …*um* of Nos …and 69.		65		0·5	6	29	28	18	15·5
…ct from soil …ditto.		140		53	17.25	21·5	3·25	3	1·88
…of *rhododen-* …*ferrugine-* … raised on a …ceous earth …Nos. 68 and		620							
…ct from the …ceding soil.		142		24	13	17	14	10	1·88

SECT. XXXIII.

OF METALS.

Several metallic substances have also been foun the ashes of vegetables, but their quantity is exceedir small; so small, indeed, that without very delicate periments their presence cannot even be detected.

The metals hitherto discovered are iron, which is far the most common, manganese, and, if we beli some chemists, gold.

1. Iron has been found in many plants; the ashe salsola contain a considerable quantity of it. From experiments of Mr Grimshaw, it appears that six o ces of cotton cloth, unbleached, contain about four gr of iron, and six ounces of linen in the same state al three grains; but it is likely, as Mr Grimshaw' serves, that part of this iron is communicated to cloth by the weaver's dressing. When it gets acid, is allowed to remain in iron pans, it must take up a of the metal *.

2. Scheele first detected manganese in vegetable Proust found it in the ashes of the pine, calendula, v green oak, and fig-tree ‡.

* *Phil. Mag.* xvi. 33. † *Opusc.* i. 106. ‡ *Phil. Mag.* v

3. With respect to the minute portion of gold extracted from the ashes of plants by Kunkel, Sage, &c. it is probable that it proceeded rather from the lead which they employed in their processes than from the ashes.

SECT. XXXIV.

OF VEGETABLE PRINCIPLES IN GENERAL.

In the preceding Sections a pretty full account has been given of the different vegetable principles hitherto examined by chemists. They amount to no fewer than 33 genera. But the three last of these, namely, the alkalies, earths, and metals, occur usually in such small proportions, that they are scarcely entitled to the name of vegetable principles. Besides, it is highly probable that they are taken up ready formed, and deposited without alteration in the vegetables which contain them; whereas the other 30 genera consist of substances which owe their formation to the processes of vegetation. It is of them, of course, that vegetables are formed; they are the substances which come into view when vegetables are analysed. It is necessary therefore to be well acquainted with their essential characters, that we may know the marks by which they are to be recognised. These unfortunately are sometimes ambi-

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gnous; so that a good deal of skill and experience are necessary before we can distinguish them readily. Some of them indeed are so imperfectly known, that we are in possession of no good characteristic marks. The following Table contains a general view of the most striking properties of the different genera.

Table of essential characters.

1. *Sugar.*—Crystallizes. Soluble in water and alcohol. Taste sweet. Soluble in nitric acid, and yields oxalic acid.

2. *Sarcocoll.*—Does not crystallize. Soluble in water and alcohol. Taste bitter sweet. Soluble in nitric acid, and yields oxalic acid.

3. *Asparagin.*—Crystallizes. Taste cooling and nauseous. Soluble in hot water. Insoluble in alcohol. Soluble in nitric acid, and converted into bitter principle or artificial tannin.

4. *Gum.*—Does not crystallize. Taste insipid. Soluble in water, and forms mucilage. Insoluble in alcohol. Precipitated by silicated potash. Soluble in nitric acid, and forms saclactic and oxalic acids.

5. Mucus. Does not crystallize. Taste insipid. Soluble in water, and forms mucilage. Insoluble in alcohol. Not precipitated by silicated potash. Precipitated by alcohol from water in a fibrous form without rendering the liquid opaque.

6. *Ulmin.*—Does not crystallize. Taste insipid. Soluble in water, and does not form mucilage. Precipitated by nitric and oxymuriatic acids in the state of resin. Insoluble in alcohol.

7. *Inulin.*—A white powder. Insoluble in cold water. Soluble in boiling water; but precipitates unaltered after the solution cools. Insoluble in alcohol. Soluble in nitric acid, and yields oxalic acid.

8. *Starch*.—A white powder. Taste insipid. Insoluble in cold water. Soluble in hot solution; opaque and glutinous. Precipitated by infusion of nutgalls; precipitate redissolved by a heat of 120°. Insoluble in alcohol. Soluble in dilute nitric acid, and precipitated by alcohol. Yields with nitric acid oxalic acid, and a waxy matter.

9. *Indigo*.—A blue powder. Taste insipid. Insoluble in water, alcohol, ether. Soluble in sulphuric acid. Soluble in nitric acid, and converted into bitter principle and artificial tannin. Volatilized by heat in a purple smoke.

10. *Gluten*.—Forms a ductile elastic mass with water. Partially soluble in water; precipitated by infusion of nutgalls and oxymuriatic acid. Soluble in acetic acid and muriatic acid. Insoluble in alcohol. By fermentation becomes viscid and adhesive, and then assumes the properties of cheese. Soluble in nitric acid, and yields oxalic acid.

11. *Albumen*.—Soluble in cold water. Coagulated by heat, and becomes insoluble. Insoluble in alcohol. Precipitated by infusion of nutgalls. Soluble in nitric acid.

12. *Fibrin*.—Tasteless. Insoluble in water and alcohol. Soluble in diluted alkalies and in nitric acid. Soon putrefies.

13. *Bitter principle*.—Colour yellow or brown. Taste bitter. Equally soluble in water and alcohol. Soluble in nitric acid. Precipitated by nitrate of silver.

14. *Extractive*.—Soluble in water and alcohol, insoluble in ether. Precipitated by oxymuriatic acid, muriate of tin, and muriate of alumina; but not by gelatine. Dyes fawn.

15. *Tannin*.—Taste astringent. Soluble in water

Book IV. and in alcohol of 0·810. Precipitated by gelatine, m riate of alumina, muriate of tin.

16. *Narcotic principle.*—Crystallizes. Sparingly luble in hot water and alcohol.

17. *Fixed oils.*—No smell. Insoluble in water, cohol. Form soaps with alkalies. Coagulated earthy and metallic salts.

18. *Wax.*—Insoluble in water. Soluble in alcoh ether, oils. Forms soap with alkalies. Fusible.

19.—*Volatile oil.*—Strong smell. Insoluble in wat soluble in alcohol. Liquid. Volatile. Oily. nitric acid inflamed, and converted into resinous su stances.

20. *Camphor.*—Strong odour. Crystallizes. In luble in water; soluble in alcohol, oils, acids; insolu in alkalies. Burns with a clear flame, and volatili before melting.

21. *Bird-lime.*—Viscid. Taste insipid. Insolu in water. Partially soluble in alcohol. Very solu in ether; solution green.

22. *Resins.*—Solid. Melt when heated. Insolu in water. Soluble in alcohol, ether, and alkalies. luble in acetic acid. By nitric acid converted into tificial tannin.

23. *Guaiacum.*—Possesses the characters of res but dissolves in nitric acid, and yields oxalic acid no tannin.

24. *Balsams.*—Possess the characters of the res but have a strong smell; when heated, benzoic a sublimes. It sublimes also when they are dissolved sulphuric acid. By nitric acid converted into artifi tannin.

25. *Caoutchouc.*—Very elastic. Insoluble in wa and alcohol. When steeped in ether, reduced to a pu

Chap. I.

hich adheres to every thing. Fusible and remains li-uid. Very combustible.

26. *Gum resins.*—Form milky solutions with wa-r, transparent with alcohol. Soluble in alkalies. /ith nitric acid converted into tannin. Strong smell, ittle, opaque, infusible.

27. *Cotton.*—Composed of fibres. Tasteless. Very mbustible. Insoluble in water, alcohol, and ether. luble in alkalies. Yields oxalic acid to nitric acid.

28. *Suber.*—Burns bright and swells. Converted nitric acid into suberic acid and wax. Partially so-ble in water and alcohol.

29. *Wood.*—Composed of fibres. Tasteless. Inso-ble in water and alcohol. Soluble in weak alkaline y. Precipitated by acids. Leaves much charcoal hen distilled in a red heat. Soluble in nitric acid, and elds oxalic acid.

But these are not the only substances which occur the vegetable kingdom. It cannot be doubted that ere are several others easily recognized by their pe-liar properties in certain vegetable bodies; though emists have not yet succeeded in obtaining them in a parate state, and in ascertaining their characters with ecision. It was this deficiency of precise informa-on that induced me to omit them; for nothing can be ore hazardous than to swell the list of vegetable con-ituents, by introducing supposed substances from gue analogies and imperfect experiments.

Acrid principle.

There are many vegetable substances remarkable for peculiar acrid property. Most of the *ranunculi*, the *olygonum hydropiper*, *mustard*, &c. are well known stances. In some of these, the acridity disappears on ying, while in others, as *mustard*, it remains. In

Book IV.

some, as the ranunculi, the acrid portion is taken up by water; while in mustard water dissolves only a very small part, and acquires the taste of garlic. This acrid property certainly depends upon the presence of some principle or principles with which we are unacquainted.

We are equally ignorant of the nature of the peculiar liquid to which the leaves of the common nettle owe their property of irritating the skin. We do not know the substance which gives the alliaceous tribe their peculiar taste and smell; a substance amazingly penetrating, but which is destroyed or dissipated by the heat of boiling water. We know little of the nauseous principle to which squills owe their virtues; and still less, if possible, of the poisonous juices with which many vegetables are filled. Indeed the only vegetable poison with which we can say we are acquainted is *prussic acid*. These are but a small number of instances, but abundance of others will occur to every reader. Indeed whole regions of the vegetable kingdom remain still unexplored. Much curious information may be expected from the analysis of the *fungi*, and other kindred plants; from the analyses of the *algæ*, and of the *lichens*. The last have indeed been examined by Hoffmann and Westring, but only with respect to their colouring matter.

Vegetable analysis imperfect.

Indeed the state of the chemical analysis of vegetables is still very imperfect. No general rules have yet been laid down; no successful method has yet been ascertained. In every particular case the analyst must follow his own judgment, and be guided by his own experience. Thus every one is obliged, in some measure, to invent a method for himself, and to create the whole as it were anew. Thus much time is wasted before the chemist is upon a level with his predecessors; and

ry one striking, as it were, from the same point, the gress is much slower than it otherwise would be. Chap. I.

The older chemists confined their analysis entirely lestructive distillation. By this process they obed nearly the same products from every vegetable. every plant when distilled yields water, oil, acid, carbureted hydrogen and carbonic acid gas; while siduum of charcoal remains in the retort. For the introduction of solvents we are indebted to the aiecaries. The experiments of Boerhaave and Neun were doubtless of value; but it was Rouelle who made the great step in vegetable analysis, by pointout the uses of various solvents to separate the difnt constituents of vegetables from each other. He the first that attempted a precise description of the table principles, and that gave marks by which r presence might be ascertained. The next great was made by Scheele, who detected the different s of vegetables, ascertained their properties, and ted out the method of separating them from those table substances into which they enter as constitu-. The experiments of some of the German ches, especially of Hermbstadt, added considerably to discoveries of Rouelle and Scheele, and made us r acquainted with some of the constituents of vebles. But of all the modern chemists none is end to greater praise than Vauquelin. His analyses been numerous, and his discoveries important. He introduced into the subject that precision which nguishes all his researches, and his method has been wed by all the other French chemists. Fourcroy been often associated with Vauquelin, and his ana- of the quinquina, which he published alone, is en-

Improvements of Rouelle.

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titled to very great praise. Proust has lately tu his attention to the same subject, and has alread voured the world with very instructive papers. lately the analysis of vegetable substances was al entirely overlooked by British chemists; but the ness of the field has now begun to attract their a tion. Experiments of great importance have been lished by Davy, Chenevix, &c. and above al Hatchett, to whom vegetable chemistry lies t deep obligations; and we may expect still more portant information from the zeal and skill of thos lightened philosophers. A few years will prob change the appearance of this branch of chemistr most entirely, and bring it nearer to the state w the chemistry of minerals has already acquired.

Thus we have examined all the substances w have been hitherto examined from vegetables. I nalysing each of them, or by exposing them repea to destructive distillation, combustion, &c. we co last to those bodies which we are at present oblig consider as simple, because they have not yet bee compounded, and of which accordingly we must pose that vegetables are ultimately composed. T amount to 15, namely,

Substances found in plants.

1. Oxygen	9. Manganese
2. Sulphur	10. Potash
3. Phosphorus	11. Soda
4. Carbon	12. Lime
5. Hydrogen	13. Magnesia
6. Azote	14. Silica
7. Muriatic acid	15. Alumina
8. Iron	

But of these substances there are twelve which compose but a very small proportion indeed of vegetables. Almost the whole of vegetable substances are composed of four ingredients, namely,

Carbon	Oxygen
Hydrogen	Azote

Of these the last, namely azote, forms but a small proportion even of those vegetable substances of which it is a constituent part, while into many it does not enter at all: so that, upon the whole, by far the greater part of vegetable substances is composed of carbon, hydrogen, and oxygen. I do not mention caloric and light; concerning the nature of which too little is known to enable us to determine with certainty into what substances they enter.

The substances at present known to chemists, which they have not been hitherto able to decompose, amount (omitting caloric and light) to about 47. Fifteen of these exist in plants; the rest belong exclusively to the mineral kingdom: for it is a fact, that no substance (I mean simple substance) has been hitherto found in the animal kingdom which does not exist also in vegetables.

On the contrary, all the simple substances at present known may be found in minerals. This indeed ought not to surprise us, if we recollect that the spoils of animals and vegetables, after they have undergone decomposition, are ultimately confounded with minerals, and consequently arranged under the mineral kingdom. Besides, if vegetables draw their food from the mineral kingdom, it would be absurd to suppose that they contain substances which they could not have procured from minerals.

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CHAP. II.

OF THE PARTS OF PLANTS.

We have, in the preceding Chapter, enumerated and described the different substances hitherto detected in plants. But a more difficult task remains for the present Chapter; namely, to explain the composition of each vegetable organ in all the numerous families of plants which constitute the vegetable kingdom. This task, indeed, in the present state of vegetable chemistry, cannot be fulfilled. By far the greater number of plants have never been examined at all; and even of those which, from their medicinal virtues or nutritive qualities, have attracted the attention of chemists, only particular organs have been analysed, while the rest have been neglected as unworthy of notice. Nothing, therefore, either resembling a complete view, or an exact arrangement, is to be looked for in this Chapter. I shall satisfy myself with stating the most important facts hitherto discovered respecting the composition of plants, as far as I am acquainted with them, under the thirteen following heads:

Chap. II.

1. Sap	8. Seeds
2. Juices	9. Fruits
3. Wood and roots	10. Bulbs
4. Bark	11. Lichens
5. Leaves	12. Mushrooms
6. Flowers	13. Diseases
7. Pollen	

se form the subjects of the following Sections.

SECT. I.

OF THE SAP OF PLANTS.

Definition.

s the general opinion of physiologists, that plants ive a considerable part of their nourishment by the ; that it enters into them in a liquid state, and s up in proper vessels towards the leaves. This d is distinguished by the name of *sap*. In the g, when the buds begin to expand themselves into s, if we break off the extremity of a branch, or nto the wood of a tree, this sap flows out, and may btained in considerable quantities. It was first exied by Dr Hales; but chemical analysis had not e sufficient progress in his time to enable him to tain its constituents. Deyeux and Vauquelin have e recently analysed the sap of different trees. To n we are indebted for most of the facts known reing this liquid.

he sap in all the vegetables hitherto examined is

Book IV. Constituents.

nearly as liquid as water. It always contains an acid, sometimes free, but more commonly combined with lime and potash. Various vegetable principles are also present: of these sugar is the most remarkable, and mucilage. Sometimes albumen and gluten, and sometimes tannin, can be detected. When left to itself the sap soon effervesces and becomes sour; or even vinous, when the proportion of sugar is considerable.

Hitherto the sap of a few species of trees only has been examined. We are not in possession of any means of collecting the sap of the inferior orders of plants. The expressed juices of a considerable number of vegetables, indeed, have been prepared for medicinal purposes; but these are not sap, but a collection of all the liquid substances which the plant contained. At present, then, it is not possible to present a general view of the properties of sap. The following are the particular species which have been examined.

1. *Sap of the Elm, ulmus campestris.*

Vauquelin collected three different specimens of the sap of this tree; the first portion towards the end of April, the second in the beginning of May, and the third about the end of May. It had a reddish brown colour; its taste was sweet and mucilaginous; and it scarcely altered the colour of the infusion of litmus. Ammonia, barytes, and lime water throw down a copious yellow-coloured precipitate, which dissolves with effervescence in acids. Oxalic acid and the nitrate of silver throw down a white precipitate. Diluted sulphuric acid occasions a brisk effervescence, and disengages the odour of acetic acid. Oxymuriatic acid de-

Properties.

stroys the colour of the sap, and throws down a brown precipitate. Alcohol produces a flaky precipitate. When evaporated by a gentle heat, a pellicle forms on the surface; brown flakes precipitate, and an earthy matter is deposited on the sides of the vessel. The earthy matter was a mixture of carbonate of lime and vegetable substance. The liquid, after depositing these bodies, and being evaporated to $\frac{9}{10}$ths of its original bulk, contained a considerable portion of acetate of potash.

Constituents.

1039 parts of this sap were composed, according to Vauquelin's analysis, of

1027·904	water and volatile matter
9·240	acetate of potash
1·060	vegetable matter
0·796	carbonate of lime

The vegetable matter was partly extractive and partly mucilaginous *.

Changes of the sap by vegetation.

On analysing the same sap somewhat later in the season, Mr Vauquelin found the quantity of vegetable matter a little increased, and that of the carbonate of lime and acetate of potash diminished. Still later in the season the vegetable matter was farther increased, and the other two ingredients farther diminished. The carbonate of lime was held in solution by carbonic acid, of which there existed a considerable excess in the sap. It is to this acid gas that the air bubbles, which so often accompany the sap as it issues from the tree, is owing †.

* *Ann. de Chim.* xxxi. 20.

† See Coulomb, *Jour. de Phys.* xlix. 392.

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2. Sap of the Beech, fagus sylvatica.

Vauquelin collected two different specimens of this sap; the first in the end of March, the second about the end of April. It had a reddish brown colour, and a taste similar to the infusion of tan. It slightly reddened vegetable blues. Barytes, ammonia, carbonate of potash, and oxalate of ammonia, occasion precipitates in it; oxymuriatic acid throws down yellow flakes; sulphuric acid blackens it, and disengages the odour of acetic acid; sulphate of iron strikes a black, and glue throws down a copious whitish precipitate. When gently evaporated to dryness, it leaves a brown extract amounting to about $\frac{1}{458}$ of its weight, ductile while hot, but brittle when cold, and having the smell and somewhat of the taste of new baked bread. It absorbs moisture from the atmosphere, and increases in weight about $\frac{1}{7}$th. Lime disengages ammonia, and sulphuric acid acetic acid, from this extract. Alcohol dissolves only a small part of it. This sap contained the following ingredients:

Properties.

Constituents.

Water
Acetate of lime with excess of acid
Acetate of potash
Gallic acid
Tannin
A mucous and extractive matter
Acetate of alumina

It contained, besides, a colouring matter, which may be fixed on cotton and linen by means of alum, and dyes them of a fine solid reddish brown colour *.

* *Ann. de Chim.* xxxi. 26.

Chap. II.

3. *Sap of the Hornbeam, carpinus sylvestris* *.

Properties.

Three specimens of this sap were collected by Vauquelin during the months of March and April. It was limpid, and its colour was whitish; its taste slightly sweet, and its smell analogous to that of whey. Barytes throws down from it a copious white precipitate, soluble in muriatic acid. Carbonate of potash likewise throws down a precipitate, soluble in acids with effervescence. Sulphuric acid deepens the colour, and evolves the odour of vinegar. Oxalic acid throws down a copious precipitate, and nitrate of silver gives the solution a fine red colour. 3918 parts, when distilled, left an extract of a reddish yellow colour, amounting to 8·279 parts. It had a sharp taste, and attracted humidity from the air.

When the extract is digested in alcohol, about the half of it dissolves. This portion consists of extractive, a saccharine matter, and acetate of potash. The residue, which is soluble in water, consists of mucilaginous matter, acetate of lime, and a colouring substance.

Action of the air.

When this sap was left exposed to the air in an open glass vessel, it became milky, disengaged carbonic acid, acquired a spirituous smell and taste, and its acidity increased. After some weeks this odour was dissipated, and carbonic acid was no longer extricated. Its acidity continued still to increase, white flakes fell to the bottom, and the liquid became transparent. After 50 days the acidity was found diminished, a mucous pel-

* I presume the *carpinus betulus* is meant.

Book IV.

licle formed on the surface, which became at last
ish brown, and the liquid had only a mouldy tas
a close bottle the sap never became transparen
when the bottle was opened after three mont
air which it contained was found converted int
and carbonic acid. The liquid had a very stro
of vinegar *.

4. *Sap of the Birch, betulus alba.*

Properties.

The sap of this tree is colourless; it has
taste; reddens vegetable blues. Neither ammo
cohol, nor oxymuriatic acid, produce any chang
it. Barytes and lime throw down a precipitate
dissolves in muriatic acid. Hydrosulphurets, s
of iron, and glue, produce no effect. Oxalic acid
down a white precipitate. Sulphuric acid dis
the odour of vinegar. Nitrate of silver strike
colour. When evaporated to about $\frac{1}{7}$th, it let
reddish brown powder insoluble in water. Wh
parts of the sap were evaporated to dryness, they
parts of brown extract. This had an agreeabl
attracted moisture from the atmosphere, and
most completely soluble in alcohol. When this
is dissolved in water and mixed with yest, it fe
and the fermented liquor yields a considerable
tion of alcohol; it yields also a considerable po
vinegar. Vauquelin did not succeed in his atte
obtain crystallized sugar from this sap; but h
tained that it contained a portion of extractive
dyes wool of a brownish yellow colour. Ac

Fermented.

* *Ann. de Chim.* xxxi. 31.

ime and of alumina were also present, and probably lso acetate of potash *. Chap. II.

5. *Sap of the Yoke Elm.*

This sap has a bitter taste. When evaporated to ryness it leaves a brown extract, in which crystals of itrate of potash are gradually formed. This extract ras scarely soluble in alcohol. It gave traces of the resence of acetate of potash and acetate of lime †. Properties.

Such are the experiments made on sap by Vauquein. All the saps examined contained acetic acid combined with lime and potash. Carbonate of lime with xcess of acid was also sometimes present; and all of hem contained some vegetable matter or other, which aried in its nature according to the plant from which it was extracted. The sap of the birch contained sugar, that of the beech gallic acid and tannin, and that of the elm and yoke elm, mucilage. Every sap contained also a portion of extractive, to which we may perhaps ascribe the ammoniacal odour emitted when the extract of these saps is burnt ‡. Much is still wanting before we can venture to draw any general inferences from these facts.

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* *Ann. de Chim.* xxxi. 36. † Ibid. p. 38.

‡ I have not had an opportunity of seeing the dissertation of Deyeux on this subject. He examined the sap of the vine and yoke elm, and discovered the acetates, and a matter which he compared to the curd of milk.

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SECT. II.

OF THE PECULIAR JUICES.

Nature.

THE sap passes from the roots in peculiar ves the leaves, where it is altered by a process sim that of digestion in animals, and formed into all quid substances requisite for the purposes of the These liquids flow from the leaves towards the appropriate vessels, and have received the name *peculiar juices* of vegetables. They differ very derably from each other in different plants. The all a certain degree of consistency, and always c much more vegetable matter than the sap. In th sent state of vegetable chemistry, an accurate de their properties cannot be attempted. Indeed it i difficult to procure them from many plants un with the sap. They sometimes exude spontane and may always be procured in smaller or g quantity by incisions through the bark of the containing them. The following are the species culiar juices which have been hitherto attended t

Milky juices.

1. *Milky juices.*—Many plants, when wounded a considerable quantity of a milky liquid, which in most cases at least, be considered as one of th culiar juices of the vegetable from which it flows. nature of this juice is extremely various.

The root of the *campanula rotundifolia* yields a juice, of a peculiar, and not unpleasant smell and

Children in some parts of Scotland collect the plant for the sake of this juice, which they suck with avidity. Its chemical properties have not been examined. Chap. II.

The different species of *euphorbia* yield a milky juice, which has a hot taste analogous to that of pepper, but more acrid, and which continues for a long time in the mouth. When oxymuriatic acid was poured into this juice, a very copious white precipitate fell down. This powder, when washed and dried, had the appearance of fine starch, and was not altered by keeping. It was neither affected by water nor alkalies. Alcohol, assisted by heat, dissolved two-thirds of it; which were precipitated by water, and had all the properties of resin. The remaining third part possessed the properties of the *woody fibre*. Mr Chaptal tried the same experiment on the juices of a great number of other plants, and he constantly found that oxymuriatic acid precipitated from them *woody fibre* *. Euphorbia.

The different species of the poppy (*papaver*) and lettuce (*lactuca*) yield a milky juice, which possesses narcotic qualities, and is distinguished by a peculiar taste and smell. These juices have been more examined than the preceding. They are of a very complex nature, containing a great variety of constituents. Gum and resin, and extractive, are the most prominent of these; and if the experiments of Derosne concerning the peculiar narcotic principle which he detected in opium, and which have been detailed in the preceding Chapter, be confirmed, we must consider that principle as constituting an essential ingredient in these juices. Poppy.

* *Ann. de Chim.* xxi. 285.

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Caoutchouc

The milky juice which exudes from the *jatroph elastica*, the *hevæa caoutchouc*, the *artocarpus integrifolia*, the *urceola elastica*, and from several other plant gradually becomes inspissated when exposed to the ai and constitutes caoutchouc. This juice has been h therto examined only by Fourcroy. Though kept i close vessels, the caoutchouc for the most part grad ally separates, and forms a white solid elastic mas The juice, however, still continues milky. When eva porated in the open air, a pellicle of caoutchouc gr dually forms on the surface, and when this is remove another succeeds. Fourcroy ascribes this formation t the absorption of oxygen from the atmosphere. B sides the caoutchouc, Fourcroy obtained from the jui transparent prismatic crystals, which had a sweet tast and which he considered as saccharine matter approach ing to the nature of an acid *.

Papaw.

The juice of the papaw tree possesses properti which distinguish it from most others. According t the analyses of Vauquelin, detailed in the precedin Chapter, its constituents resemble very closely the con stituents of blood.

Besides the milky juices enumerated above, there a many others. Almost all the gum resins indeed a originally in that state; but as no chemical analysis o these juices has yet been made, it is needless to dwe upon them †.

Mucilaginous juices.

5. *Mucilaginous juices.*—The peculiar juices of man

* *Ann. de Chim.* xi. 225.

† The reader may consult a dissertation on the milky juices of pl by Carradori. See Gehlen's *Jour.* vi. 630.

plants are not milky, and some not distinguished by any strong taste or smell. In these mucilage seems to be the predominating matter. Under this head may be reckoned the juices of most of the mucilaginous plants enumerated in the fifth Section of the preceding Chapter. Chap. II.

The substance called *cambium*, too, if we may be allowed to consider it as a peculiar juice, since it is obviously different from the sap, is entirely mucilaginous. It makes its appearance, according to Mirbel, in all those parts of vegetables where new matter is to be formed, and seems necessary for all such formations, either as the matter employed in their formation, or as furnishing a proper bed for them to be formed in. It does not appear to be confined in vessels like the other juices *. Cambium.

3. Some juices are intermediate between volatile oils and resins. These may be distinguished by the name of *turpentines*. Common turpentine, balsam of copaiva, and probably also opobalsamum, belong to this class. These juices are originally limpid and transparent, have a strong smell and taste, and gradually acquire consistency by exposure to the air, probably by absorbing oxygen. Turpentine.

4. Other juices obtained by excision possess at first the properties of resins, or at least acquire them before they are brought into this country. Such, for example, are tacahamac and mastich, and most of the resinous bodies described in Section XXIII. of the preceding Chapter. Resins.

5. Others are entitled to the name of *balsam*, accord- Balsams

* Mirbel, *Ann. de Mus. d'Hist. Nat.* No xl. p. 294.

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ing to the strict meaning of the word; as balsam of tol of Peru, styrax, and benzoin.

Tannin.

6. Some peculiar juices are composed almost entirel of tannin, or at least are characterised by containing superabundance of that substance. Such probably ar the juices of oak, sumach, and of most vegetables tha yield abundance of the tanning principle. In som cases, it would seem that these juices exude spontane ously; though in general they are obtained by artifici means.

Sugar.

7. Some vegetables possess juices characterized b the great quantity of sugar which they contain. Such for example, as the sugar-cane, the carrot, and the vari ous species of beet. For it is surely more reasonable t consider the saccharine matter in these plants as be longing to the peculiar juices than as confined to th sap.

Saline matter.

8. Finally, the peculiar juices of some plants a characterized by containing a considerable proportion saline matter. Thus the various species of sorrel con tain a notable quantity of superoxalate of potash, an several of the sedums malate of lime. In short, th peculiar juices of plants are nearly as numerous as th vegetable principles themselves; and when the fung algæ, lichens, and several other of the numerous inf rior tribes of vegetables have been once examined, cannot be doubted that the number will greatly i crease.

Braconnot has lately examined the juices of a numb of plants, in order to ascertain the peculiar acids whic

tained. The following is a short abstract of lts which he obtained *. Chap. II.

expressed juice of the *aconitum lycortonum* evato dryness and incinerated leaves about 0·01 of e of potash. This juice contains a considerable on of citric acid, partly combined with potash ly with lime. Perhaps also malic and acetic present in the juice of this plant.

uice of the *delphinium elatum*, the *ranunculus lius*, the *thalictrum flavum*, the *clematis recta* and likewise contains a quantity of citric acid like eding juice.

uice of the *salvia sclarea* contains benzoic acid combined with potash.

uice of the *ruta graveolens* contains malic acid d with potash and with lime.

uice of the *eupatorium cannabinum* contains an ich appears to be the malic mixed with some ric.

uice of the *nicotiana rustica* and *tabacum* conlic acid combined with potash and lime.

uice of the *mirabilis jalapa* contains nitric acid, acid, malic acid, and a little sulphuric acid combined with potash.

pinacia oleracea contains oxalates of lime, and h, malate and phosphate of potash.

tropæolum majus contains phosphoric acid, nitric d malic acid united to lime and to potash.

ricinus communis contains malic acid doubtless ed with potash.

* *Ann. de Chim.* lxv. 277.

Book IV. The *phytolacca decandra* contains an uncommon proportion of potash, and an acid which possesses the properties of the oxalic.

SECT. III.

OF THE WOOD AND ROOTS.

The roots of a great variety of plants are employed in medicine and the arts; but few of them have been hitherto subjected to chemical examination. The substances found in them are various; and indeed, as the peculiar juices of the roots are always included in such examinations, it is clear that almost all the vegetable principles will be found in them.

The process usually followed in examining these substances, is first to separate every thing soluble in cold water, then to boil the root in water. Alcohol is applied next; and afterwards different acids or alkalies, according to the nature of the substances suspected to be present. The roots of the following plants have been subjected to chemical examination:

List.

Helleborus hyemalis	Convolvulus jalappa
Brionia alba	Gentiana lutea
Calaguala	Rheum palmatum
Ho-ang-lien	Rubia tinctorum
Cephælis, or calicocca ipecacuanha	Curcuma longa
	Valeriana officinalis

Helleborus hyemalis.—The root of this plant is tu-us, has a yellowish white colour, and is covered a black skin. At first it has no taste; but in a time a strong acridity becomes sensible in the h and throat. Vauquelin has lately subjected it to mical examination, chiefly in order to ascertain the e of the bitter and acrid principle which it con-. This principle he found to be an oil of a pecu-nature, possessing properties intermediate between xed and volatile oils. He obtained it by digesting oot in alcohol, and then distilling off the alcohol in embic. The oil gradually separated and concreted oling. Its taste was extremely acrid, and it had a wish brown colour. When dissolved in weak al-, it precipitates the sulphates of iron of a fine pur-red colour, which becomes green by means of al-s. This oil is extremely poisonous, and, accord-o Vauquelin, exists in many plants, and is the of their poisonous qualities. Helleborus hyemalis. Contains a poisonous oil.

hen the root is digested in water, and the liquid d through a cloth, it is obtained opaque and milky, radually deposites a white powder which possesses roperties of starch. The liquid, by evaporation, sites a brownish matter, which forms successive cles on the surface. This substance possesses the erties of extractive. Besides these substances, quelin detected a substance analogous to gluten, e sugar, and a portion of woody fibre *.

. *Brionia alba.*—This root has been used in medi-e, and was known to contain a considerable portion Brionia alba.

* *Ann. de Mus. d'Hist. Nat.* No. xliii. 82.

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of starch, and a bitter principle soluble in wat alcohol. Vauquelin lately examined it. By r tion in water, and subsequent pressure in a line: the starch was separated and obtained in a state ty. The bitter substance was soluble both in and water, and appeared to possess the prope pure bitter principle. The root was found lik contain a considerable portion of gum; a su which is precipitated by infusion of galls, and Vauquelin denominates *vegeto-animal matte* woody fibre, a small portion of sugar, and a qua supermalate of lime and phosphate of lime *.

Constitu-ents.

Calaguala.

3. *Calaguala root.*—This is a root brougl America for medicinal purposes, which has a considerable celebrity on the continent. The pl which it is obtained is not known; but from th vations of Vauquelin is supposed to be a sp *polypodium*. It has a brown colour, is partly ed with scales like the roots of fern, and is ve and difficult to reduce to powder. Vauquelin, lately subjected it to analysis, found it a very c substance, and separated from it no fewer than lowing substances:

Constitu-ents.

Woody fibre	Colouring matter
Gum	Malic acid ?
Resin	Muriate of potash
Sugar	Lime
Starch	Silica

Alcohol dissolves the resin and sugar. By evap

* *Ann. de Mus. d'Hist. Nat.* No. xliii. 88.

the solution to dryness, and treating the residue with water, the sugar is separated and the resin left. This resin has a reddish brown colour, and a bitter and acrid taste. It dissolves in alkalies, communicating a brown colour and a bitter taste, and is again separated by acids. Vauquelin suspects that this principle is the constituent of the root, both of this plant and of the other filices which possess vermifuge properties. Water dissolved the gum and the muriate of potash, which were obtained by evaporation. Diluted nitric acid dissolved the starch and the colouring matter, and let fall the former when mixed with four times its bulk of alcohol. The woody fibre remained, which when incinerated left carbonate of lime, muriate of potash, and a little silica. As the decoction reddened vegetable blues, it is possible that the lime was in combination with malic acid *.

Ho-ang-lien.

4. *Ho-ang-lien.*—This is a bitter tasted root, brought from China, and used on the continent as a medicine. It has been slightly examined by Bouillon la Grange. From his experiments, it seems to owe its properties chiefly to the bitter principle, of which it contains a considerable portion. It contains also a resinous matter, taken up by alcohol and thrown down by water. This substance when dry has a brown colour, melts when heated, and burns, emitting an aromatic odour †.

Ipecacuan

5. *Ipecacuan.*—This is the root of a plant which grows spontaneously in Brazil, and probably in other parts of South America. It was first correctly described and figured by Dr Brotero, under the name of *cal-*

* Vauquelin, *Ann. de Chim.* lv. 22.

† Ibid. p. 40.

Book IV. *licocca ipecacuanha* *. The root is about the thic of a quill, unequal and knotty, and varies conside in its colour. When pounded it forms the m and safest emetic in the whole Materia Medica. Th probably employed in America from time immem it was not introduced into Europe till the time of l XIV. when one Grenier, a French merchant, br 150lbs. of it from Spain; with which trials were at the Hotel Dieu. Helvetius first made known i in dysentery, for which he was rewarded by I XIV. with L. 1000 sterling †.

Properties. This substance, notwithstanding its importan medicine, has not hitherto been subjected to an acc chemical examination. The most recent experi are those of Dr Irvine, who gained the prize o Herveyan Society, at Edinburgh, for the year 1 From his experiments, it appears to contain a gu resinous matter, in which its activity chiefly re Probably, also, pure resin and extractive are to be f in it. When the root is long boiled in water, its vity is destroyed. When distilled along with w the liquid that comes over is inactive; but the d tion which remains in the alembic acts with viol upon the system.

Jalap. 6. *Jalap*.—This very active cathartic is the ro the *convolvulus jalappa*, a plant which is a nati Xalapa, a province of New Spain ‡. It is broug Europe in thin slices, which are hard, of a brow lour, exhibiting resinous streaks and circles, easil

* *Linnean Trans.* vi. 137.

† Neumann's *Chem.* p. 357.

‡ Hence the term *Jalap*. Neumann's *Chem*, p. 352.

flammable, of scarcely any smell, and a weak acrid taste. The chemical nature of this root has not been much examined. From the few experiments detailed by Neumann, it appears to contain a resin, to which its active properties are ascribed, and likewise a portion of extractive and of mucilaginous matter.

Rhubarb.

7. *Rhubarb.*—This is the root of the *rheum palmatum*, and perhaps also of some other species of rheum, brought chiefly from the northern parts of China by the way of Russia, though of late it has been cultivated also in Britain. The root is large, of an oblong or roundish shape; of a dark brown colour externally, with black and reddish streaks; internally it is reddish yellow, and when fresh contains a juice of the same colour. No accurate chemical analysis of rhubarb has yet been made; but from the experiments of Neumann, it appears that nearly one half of it is soluble in water, and that alcohol scarcely takes up any thing from the residue. From the properties of the watery extract, enumerated by that laborious chemist, we may infer, with some probability, that it consists chiefly of the extractive and bitter principle, and that it contains some tannin. A small quantity of greenish yellow resinous matter seems also to be present *. Scheele separated from the root about $\frac{1}{7}$th of its weight of oxalate of lime †. But this salt is not taken up by water.

Gentian.

8. *Gentian.*—This is the root of the *gentiana lutea*, a plant which grows spontaneously in the mountainous parts of France, Switzerland, Hungary, &c. It is said

* Neumann's *Chem.* p. 360.

† Crell's *Annals*, i. 34. Engl. Transl.

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to have been named after Gentius, a king of Illyria, who is supposed to have first discovered its virtues. The root is externally brown; internally yellow, with a spongy pith in the middle. Its taste is intensely bitter. From the experiments of Neumann, we may conclude that the soluble parts of it consist chiefly of bitter principle, mucilaginous matter, resin, and extractive. The first seems to be the most copious and most active ingredient, and the one to which it owes its medicinal properties.

Madder.

9. *Madder.*—This is the root of the *rubia tinctorum*, a plant cultivated in Zealand, &c. for the dyers. The root is the useful part, forming one of the most valuable of the red dyes. It is about the thickness of a goose quill, somewhat transparent, of a reddish colour, and a strong smell. The colouring matter of madder is the only part of this root that is valued. Mr Watt has published a dissertation on it; to which we owe almost every thing that we know respecting its chemical nature.

Properties.

It appears that there are two distinct colouring matters in madder: a red, which is extracted readily by cold water; and a brown, which requires a boiling heat to separate it in any quantity. Hence the reason that dyers are cautious not to raise the infusion of madder to a boiling temperature till towards the end of their process. Both of these colouring matters appear to possess the properties of extractive. They are soluble in water and alcohol; and when the solution is evaporated, pellicles successively form on the surface. These gradually subside, and form a reddish brown matter only imperfectly soluble in water. When alum liqu—

s poured into the infusion of madder, a deep brownish red flaky precipitate falls, and the liquid assumes a brownish yellow colour; and alkaline carbonates and lime water throw down a blood red lake, differing in the shade of its colour according to the proportion of alum employed. Acetate of lead throws down a brown-coloured precipitate.

When carbonate of magnesia is mixed with infusion of madder, the liquid assumes a bright blood-red colour; and by evaporation an extract is obtained, which readily dissolves in water, and when spread upon paper becomes yellow in a few days, if exposed to the sun.

Water, holding a little alkali in solution, forms with madder a dark brownish red solution; but if the water be mixed with a little acid, the infusion is yellowish *.

From the late observations of Merimé, it appears probable that a third colouring matter is present in madder; that it is more soluble than the red; and that it may be separated by steeping the madder a certain time in water, and then precipitating the solution with an alkali. After this a much finer red lake may be obtained from madder †.

10. *Turmeric.*—This is the root of the *curcuma longa*, a plant which grows in the East Indies. It has a fine yellow colour, a slight smell, and an aromatic bitter taste. To water it gives its own yellow colour, and the infusion is rendered brown by alkalies. To alcohol it gives a red colour, which stains hot marble of a durable colour ‡. The constituents of this root are but Turmeric.

* See Watt, *Ann. de Chim.* iv. 104.

† Berthollet, *Elemens de l'Art de la Teinture*, ii. 120.

‡ Lewis, Neumann's *Chem.* p. 384.

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imperfectly known. From the experiments of Neumann, we learn that it contains a little volatile oil; the water dissolves nearly one-third of the root, but that a very small portion only is soluble in alcohol *. It forms the chief ingredient in *curry powder*.

Valerian.

11. *Valerian.*—Trommsdorf has examined the root of the *valeriana officinalis*. It loses three-fourths of its weight by drying. Distilled with water it yields a volatile oil, very liquid, and of a greenish white colour. Its odour is strong and camphoric; its specific gravity at the temperature of 77°, is 0·9340; its taste is aromatic and camphoric without being acrid. When exposed to the light it becomes yellowish. Nitric acid converts it into a resinous substance, or, if it be used in a sufficient dose, into oxalic acid. The expressed juice of the roots of this plant is muddy, and has a strong odour. It lets fall a portion of starch. It contains a peculiar substance approaching the nature of extractive, soluble in water, but insoluble in ether, and in pure alcohol. It is precipitated from water by the salts of lead, silver, mercury, and antimony. This juice contains also a portion of gum. The roots deprived of this juice yield a portion of black coloured resin, but consist chiefly of woody fibre †.

Horse radish.

12. *Horse radish.*—Einhoff has lately examined the root of this vegetable, and found that its acridity is owing to the presence of a small quantity of volatile oil, which he obtained by distilling the mashed roots in a water bath. A liquid came over which was at first milky, but gradually deposited a little of the volatile

* Lewis, Neumann's *Chem.* p. 388.

† *Ann. de Chim.* lxx. 9[illegible]

oil in question. This oil had a pale yellow colour, and the consistence of the oil of canella. Its odour was that of horse radish excessively strong. Its taste was at first sweetish; but it left an acrid impression, and excited inflammation in those parts of the tongue and lips to which it was applied. It is heavier than water, with which it forms a milky liquid by agitation. It dissolves readily in alcohol. It is volatilized at the temperature of 60°. The liquid obtained from the roots of the horse radish by distillation yielded traces of sulphur *.

Chap. II.

Many other roots have been employed either in medicine or the arts; but as they have not yet been subjected to chemical analysis, I think it unnecessary to enumerate them here. For the same reason, out of the vast number of woods known and employed in the arts, I shall mention only the following:

Logwood.

1. *Logwood*.—This is the wood of the *hæmatoxylon campechianum*, a low prickly tree, which grows abundantly about Campeachy, on the bay of Honduras. It comes to Europe in large logs, cleared from the bark, and is very hard, compact, heavy, and of a red colour. It has a sweetish astringent taste, but no perceptible smell. It is very much used by dyers, especially in dyeing black, to which indeed it is in some degree essential. For the facts known respecting its properties, we are chiefly indebted to Dr Lewis †. Several of its constituents have lately been ascertained by Chevreul ‡.

Properties.

Logwood gives out its colouring matter both to wa-

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* *Ann. de Chim.* lxx. 185.

† Neumann's *Chem.* p. 385.

‡ *Ann. de Chim.* lxvi. 254.

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ter and alcohol; but to neither with much i
The liquors assume a fine red colour with a s
purple. The infusion becomes gradually deep
at last almost black. To cloth, previously b
alum and tartar, it gives a very beautiful, but
able violet colour. Alkalies deepen the colou
infusion; acids change it to yellow. With su
nitric, muriatic, and acetic acids, slight reddish
precipitates fall. Alum throws down a copiou
precipitate. Sulphate of iron strikes a dark
black like ink, and throws down slowly a pre
of the same colour. Sulphate of copper throw
a copious brownish black precipitate, and ac
lead an equally copious reddish black precipita
muriate of tin throws down instantly a copious
lake, while the liquid becomes transparent and
less *. Chevreul has shown that this wood co
volatile oil, tannin, a yellow colouring matter, a
tate of lime and of potash †.

Brazil wood.

2. *Brazil wood.*—This is the wood of the *ca
crista*, a tree which grows in Brazil, and like
other countries, where it is cultivated for th
The tree is very large, and the wood very h
very heavy. Its colour is at first whitish, bu
comes red by exposure to the air. Water in w
is boiled acquires a fine red colour; while the w
self, by repeated decoctions, becomes black. A
ter has ceased to act, alkaline leys still depriv
considerable quantity of colouring matter.

* Berthollet, *Elemens de l'Art de la Teinture*, ii. 244.

† *Ann. de Chim.* lxvi. 254.

likewise takes up the colouring matter of Brazil wood, and acquires a deeper colour than water. Chap. II.

From the decoction in water, sulphuric and muriatic acids throw down a scanty red precipitate, while the liquid becomes yellow. An additional dose of acid restores the red colour again. Nitric acid changes it to yellow, and then to orange. Oxalic acid throws down an orange red precipitate. The alkalies change the colour to purple, and throw down a scanty precipitate. Alum precipitates slowly a copious reddish lake, and muriate of tin an abundant rose-coloured powder, while the liquid becomes nearly colourless. Sulphate of iron strikes a black with a tint of violet, and throws down a precipitate of the same colour. Acetate of lead throws down a fine dark red precipitate *. An elaborate set of experiments on Brazil wood has lately been published by Chevreul. The following are the results which he obtained:

Properties.

The decoction of yellow Brazil wood is yellow. When distilled it yields water containing a portion of acetic acid, and a volatile oil having the odour and taste of pepper. As the liquid is concentrated by evaporation, a viscid matter is perceptible, of a brown colour, which is a compound of tannin and the colouring matter. The liquid retains a portion of the same substances. It contains also traces of ammonia, and of lime probably combined with acetic acid. Chevreul suspects also the presence of sugar and of gallic acid; both of which he detected in the extract of Brazil wood of commerce. All his attempts to separate the colour-

* Berthollet, *Elemens de l'Art de la Teinture*, ii. 229.

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ing matter from tannin, and obtain it in a sepa failed. The acids change it from yellow to r infusions containing it. Alkalies and alkal make it pass to violet. Alumina strikes a deutoxide of tin a violet, and peroxide of tin lour. Several neutral salts, as sulphate of when added in considerable quantity, change to red. Sulphureted hydrogen gas combine and destroys the colour; but it appears agair sulphureted hydrogen is separated. It has affinity for alkalies than litmus; and acco renders litmus paper red, by depriving it of with which it is in combination *.

Red saunders.

3. *Red saunders.*—This is the wood of the *pus santalinus*, a large tree which grows on mandel coast, and in other parts of India. is at first light red, but becomes very dark by to the air. It is very compact and ponderous no smell, and very little taste. This wood used for colouring drugs, and has not yet been ed to chemical examination. The colouring of a resinous nature, and probably similar t dragon's blood. It is taken up by alcohol, b water. The alcoholic tincture is a fine red, comes yellow when diluted with a large q spirits †. By this property of yielding no matter to water, we can easily distinguish red from Brazil wood; a distinction first pointed c Lewis ‡.

* *Ann. de Chim.* lxvi. 225.

† Neumann's *Chem.*

‡ Ibid p. 336.

4. *Fustic.*—This is the wood of the *morus tinctoria*, a large tree which grows in the West India islands. It is used in dyeing yellow, and is very rich in colouring matter. It is neither very hard nor heavy; its colour is yellow with orange veins. It gives a deep orange colour to water. The decoction gives a precipitate with glue, but still retains its colour. Acids throw down a slight greenish yellow precipitate, which is redissolved by alkalies. These give the decoction a dark red colour, and gradually separate a yellowish matter. Alum throws down a scanty yellow precipitate; sulphate of iron, a precipitate at first yellow, but which becomes brown; sulphate of copper, a yellowish brown precipitate; acetate of lead, an orange yellow precipitate; and muriate of tin, a very copious fine yellow precipitate *. (Fustic.)

5. *Sumach.*—This is the shoots of the *rhus coriaria*, a shrub which grows in the countries bordering on the Levant. They are cut down yearly, dried, and ground in a mill. Like the preceding substances, it is used in dyeing, and chiefly as a mordant, on account of the tannin which it contains. It gives to water a greenish yellow colour, which soon becomes brown by exposure to the air. It has not yet been subjected to a regular chemical analysis. The tannin appears to be the principal ingredient; and, according to Proust, it differs in its properties from the tannin contained in other plants. Bartholdi published a set of experiments on the decoction of this plant. According to him, it contains a great variety of saline matters; nitrate of potash, mu- (Sumach.)

* Berthollet, *Elemens de l'Art de la Teinture*, ii. 259.

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riate of soda, sulphate of lime, gallate of magnesia, carbonate of lime, &c. But these experiments stand in need of repetition *.

SECT. VI.

OF BARKS.

Bark.

THE bark is the outermost part of vegetables. It covers the whole plant from the extremity of the roots to the extremity of the branches. It is usually of a green colour: if a branch of a tree be cut across, the bark is easily distinguished from the rest of the branch by this colour. If we inspect such a horizontal section with attention, we shall perceive that the bark itself is composed of three distinct bodies, which, with a little care, may be separated from each other. The outermost of these bodies is called the *epidermis*, the middlemost is called the *parenchyma*, and the innermost, or that next the wood, is called the *cortical layers*.

Consists of three substances.

1. Epidermis.

The *epidermis* is a thin transparent membrane, which covers all the outside of the bark. It is pretty tough. When inspected with a microscope, it appears to be composed of a number of slender fibres crossing each other, and forming a kind of net-work. It seems ever

* *Ann. de Chim.* xii. 305.

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to consist of different thin retiform membranes, adhering closely together. This, at least, is the case with the epidermis of the birch, which Mr Duhamel separated into six layers. The epidermis, when rubbed off, is reproduced. In old trees it cracks and decays, and new epidermes are successively formed. This is the reason that the trunks of many old trees have a rough surface.

2. The parenchyma.

The *parenchyma* lies immediately below the epidermis; it is of a deep green colour, very tender, and succulent. When viewed with a microscope, it seems to be composed of fibres which cross each other in every direction, like the fibres which compose a hat. Both in it and the epidermis there are numberless interstices, which have been compared to so many small bladders.

3. The cortical layers.

The *cortical layers* form the innermost part of the bark, or that which is next to the wood. They consist of several thin membranes, lying the one above the other; and their number appears to increase with the age of the plant. Each of these layers is composed of longitudinal fibres, which separate and approach each other alternately, so as to form a kind of network. The meshes of this network correspond in each of the layers; and they become smaller and smaller in every layer as it approaches the wood. These meshes are filled with a green coloured cellular substance, which has been compared by anatomists to a number of bladders adhering together, and communicating with each other.

Nature of barks.

Fourcroy supposes that the epidermis is the same in its nature in all trees, and that it possesses constantly the properties of suber; but this opinion is not likely to be verified. The cortical layers seem, at least in

many cases, to have a similar fibrous basis; a basis possessing essentially the properties of flax, which is itself merely the cortical layers of the *linum usitatissimum*. The matter of the parenchyma, and the juices which exist in barks, vary extremely, and probably occasion most of the differences between them. Some, as oak bark, are characterized by their astringency, and contain tannin; others, as cinnamon, are aromatic, and contain an essential oil; others are bitter, as Jesuits bark; some are chiefly mucilaginous, others resinous, &c. But in the present state of the subject, an enumeration of the different kinds of barks is not to be expected. I shall therefore, as in the preceding Sections, satisfy myself with detailing the properties of those barks that have been subjected to examination. The following are the most remarkable of these:

Quinquina of St Domingo.

1. *Bark of the cinchona floribunda, or quinquina of St Domingo.*—This bark has been analysed with great address by Fourcroy. His analysis still constitutes one of the completest which has hitherto been made on any of the substances belonging to the vegetable kingdom.

This bark is in rolled pieces, six or seven inches long, and three or four lines in thickness. Its colour is greyish green externally, but within it exhibits different shades of green, purple, white, brown, &c. Its taste is bitter and disagreeable; its odour strong and unpleasant.

It gives out nearly half its weight to water, provided it be boiled in a sufficient quantity of that liquid. The residue possesses the properties of woody fibre. When burnt it leaves a coal, which contains the follow-

-ng saline constituents. The quantities are those ob-tained from a pound, or 9216 grains of the bark.

Earthy residue.

Carbonate of potash	10 grains
Sulphate of potash	12
Muriate of potash	38
Phosphate of lime	20
Carbonate of lime	420
Silica	4

Matter soluble.

The decoction of the bark has a reddish brown colour, and an extremely bitter taste. It deposites on cooling a blackish substance, soft and tenacious, which does not dissolve in cold water, though it is soluble in hot water and in alcohol. More of this substance precipitates as the liquor is evaporated. When the inspissated juice, freed from this precipitate, is mixed with alcohol, a quantity of gummy matter separates. When the black matter which precipitates as the decoction cools is treated with hot alcohol, the greatest part of it is dissolved; but a fine red powder remains mixed with some mucilage, which is easily separated by water. When the alcoholic solution is exposed to the air, it deposites light yellowish crystals of a saline nature. When mixed with water, white flakes are thrown down, which possess the properties of gluten; but the greatest part remains in solution. Thus the soluble part of the bark may be separated into five distinct substances; namely, *gum*, *gluten*, a *red powder*, a *saline matter*, and a *brownish bitter substance*, retained in solution by the diluted alcohol. The last is by far the most abundant. To it the peculiar qualities of the decoction of this bark are to be ascribed. The following are the quantities obtained by Fourcroy from 9216 grains of the

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Gum............	648 grains
Gluten...........	84
Red powder.......	144
Saline crystals......	72
Brownish matter...	4076
Total	5024

Properties. The gummy matter and gluten possessed very nearly the properties of these substances, as described in the last Chapter of this work. The red powder is insoluble in water and alcohol, but dissolves readily in alkalies. When distilled it yields much oil and ammonia and little water, According to Fourcroy, it is *extractive* saturated with oxygen. The nature of the saline matter was not determined in a satisfactory manner. The brownish matter which remained dissolved in the diluted alcohol, being by far the most abundant and important ingredient, was examined with particular care, From the experiments of Fourcroy, it appears to approach nearest to *extractive* in its properties.

Its colour is reddish brown, and its taste very bitter. When dry it appears black, is very brittle, and breaks with a vitreous fracture. It is insoluble in cold water, but dissolves very readily in that liquid when heated, precipitating, however, in part, as the water cools. But if one part of it be dissolved in 24 parts of hot water, no portion of it precipitates. If lime water be dropt into this solution, it throws down a reddish powder, redissolved by the addition of a sufficient quantity of water. Muriatic acid precipitates nothing from the solution. The brown matter dissolves readily in alcohol, if it be previously reduced to powder. When distilled it gives out carbonic acid and inflammable air

water impregnated with pyromucous acid, and a quantity of oil. The watery portion contains likewise ammonia. The charry residue is very bulky, ten times as much so as the original matter.

When oxymuriatic acid gas is passed through this extractive substance dissolved in water, it becomes immediately reddish, and then a precipitate of the same colour gradually falls. This precipitate possesses exactly the properties of the *red powder* obtained from the decoction of the bark; a proof that this red powder is merely the brown extractive altered in its properties by the absorption of oxygen. If the current of oxymuriatic gas be continued, the whole liquor gradually loses its colour, and the precipitate also becomes a pale yellow. If it be separated in this state by filtration, it assumes the appearance of gamboge. Alcohol dissolves it, but not a mixture of alcohol and water*.

Peruvian bark.

2. *Bark of cinchona officinalis.*—This tree grows in Quito; it is confined to the high grounds, and when stript of its bark soon dies. There are three different kinds of *bark* to be found in commerce, but whether they be all obtained from the same trees is not known; the contrary is probable. The following are the most remarkable of these varieties.

1. Red.

Red Peruvian bark.—This bark is usually in large pieces, and is reducible to powder with more ease than the preceding. Its powder is reddish brown, and has a slightly bitter taste, with a good deal of astringency. We are indebted to Fourcroy likewise for the analysis of this bark.

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* Fourcroy, *Ann. de Chim.* viii. 120.

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Water in which the powdered bark is macerated, acquires the property of reddening vegetable blues, and contains a portion of citric acid, some muriate of ammonia, and muriate of lime. When 576 parts of the bark are boiled repeatedly in water till that liquid ceases to have any action on it, the water acquires a reddish orange colour, and when evaporated to dryness leaves a residue which amounts to 38 parts. This contains a small portion of the acid and salts just mentioned, but consists chiefly of a matter which possesses nearly the properties of extractive. When the residual bark is treated with a sufficient quantity of alcohol, that liquid takes up 24 parts of a substance which has a red colour, and appears intermediate between resin and extractive. The residue of the bark possesses the properties of woody fibre. When burnt it leaves twelve parts of a grey ash, consisting of

Carbonate of potash	1·9
Muriate of potash............	0·6
Sulphate of potash	0·5
Carbonate of lime	9·0
	12·0

Such is the result of Fourcroy's analysis *. Subsequent experiments have detected a portion of resin and of bitter principle. The presence of tannin in small quantity was indicated by the property which the decoction showed of striking a black with sulphate of

* *Ann. de Chim.* viii. 174.

. The bitter principle seems to belong to the se- Chap. II.
l species, or that which was first observed in coffee.

'ellow Peruvian bark.—This species of bark, first 2. Yellow.
ght into use in this country about the year 1790,
ıot yet been subjected to a rigorous analysis; but
onstituents do not appear, from the trials which have
made, to differ much from those of the red species.
Deschamps has published a method of extracting
ı it a considerable quantity of an undescribed salt
base of lime, which Vauquelin has shown to be
te of lime. It is white, and crystallizes in plates.
process consists in macerating the bark in a suffi-
quantity of cold water, in concentrating the liquid,
setting it aside to spontaneous evaporation. The
tals gradually separate, and are purified by repeat-
rystallizations. The quantity procured amounts
bout seven parts for every hundred of bark em-
ed *.

'ale Peruvian bark.—This is the common variety 3. Pale.
e bark. It has not yet been subjected to a correct
nical analysis. Its taste is astringent and bitter, and
disagreeable. It is supposed to contain bitter
ciple, tannin, extractive, and resin. Besides these, it
ains a principle first pointed out by Seguin, and
ı which Dr Duncan junior published some expe-
ents †. It is distinguished by the property of pre-
tating infusion of galls; but as this property is
mon to a considerable number of substances, it is
sufficient alone to characterize it.

. Bark of cinchona Carribæa.—This bark was first

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* *Ann. de Chim.* xlviii. 65. † Nicholson's *Jour.* vii. 226.

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made known by Dr Wright, who published a botanical description of the tree, with a figure, in the Philosophical Transactions *; and an account of the medicinal properties of the bark in the London Medical Journal for 1787 †. A description of a tree to which the same name is given, together with a chemical analysis of the bark, was published in the Journal de Physique for 1790 ‡ by M. Vavasseur; but it is not quite certain that the plants are the same.

4. Vauquelin has lately examined all the different species of cinchona, or Peruvian bark, which he could procure, in order to determine, if possible, how far they differ from each other, and what the constituents are that act as febrifuge §.

Species of bark.

They may be divided into three sets:

I. The infusions of the first set precipitate the infusion of nutgalls, but not that of glue.

II. The infusions of the second set precipitate glue, but not the infusions of nutgalls.

III. The infusions of the third set precipitate at once glue, nutgalls, and tartar emetic.

The following Table exhibits the effects of the different reagents upon all the barks tried. As Vauquelin has not given the botanical name in all cases, it is difficult, notwithstanding his descriptions, to ascertain the real names of the different species tried. Indeed, there is reason to believe that the same species occur in different parts of the Table under different names:

* Vol. lxvii. p. 504.

† Vol. viii. p. 239.

‡ Vol. xxxvii. p. 241.

§ Ann. de Chim. lix. 113.

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Barks.	Precipitate by glue.	Precipitate by tannin.	Ditto by tartar emetic.
Yellow bark.........	White		Copious
Quinquina of Sta Fé	Reddish	Copious	0
Grey quinquina......	White	ditto	White
Quinquina gris canelle	Brown	0	0
Red quinquina........	Red	0	Yellowish white
Grey quinquina	White	Yellow	ditto
Quinquina gris plate..	0		0
Cinchona pubescens..	0	Yellow	Yellowish white
Cinchona officinalis..	0	ditto	0
Cinchona magnifolia	Copious	0	0
Quinquina pitton vrai	0	Copious	Copious

Barks brought from Peru by Humboldt.

Quinquina of Loxa...	Copious	Copious	Copious
Quin. white of Sta Fé	0	0	0
Quin. yellow of S. Fé	0	Copious	Copious
Quin. red of Sta Fé..	Copious	0	0
Q. yellow of Cuença	0	0	0
Quinquina, ordinary..	Copious	Copious	Copious
Infusion of nutgalls..	Copious		Yellow white
Oak bark................	ditto		0
Cherry-tree bark......	0	0	0

All the barks strike a green with iron, and most of them precipitate it of that colour.

The substance in these barks which precipitates tannin has a brown colour and a bitter taste; it is less soluble in water than in alcohol. It precipitates tartar emetic, but not glue. It has some resemblance in its

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properties to the resins, though it gives out ammonia when distilled.

Croton.

5. *Bark of croton eleutheria.*—This bark constitutes the eleutheria and cascarilla of the shops. It is usually in rolled pieces, and has some resemblance to Peruvian bark. It has an aromatic smell, and an agreeable bitter taste. When burnt it emits an aromatic odour resembling that of musk. For the only chemical analysis of this bark hitherto published, we are indebted to Professor Trommsdorf; 4696 parts of it yielded him the following products *.

Mucilage and bitter principle	864 parts
Resin	688
Volatile oil	72
Water	48
Woody fibres	3024
Total	4696

White willow.

6. *Bark of the white willow (salix alba).*—The bark of this tree, which is common enough in Scotland, is remarkable for its astringent taste, and has been often used in intermittents by the common people. It has lately been proposed by Bouillon la Grange as an excellent substitute for Peruvian bark; being composed, according to him, of the very same constituents to which that bark owes its medicinal virtues. A very superficial examination, however, may satisfy any one, that the properties of the two are very far from similar.

The decoction of this bark has a dark reddish co-

* *Ann. de Chim.* xxii.

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nd, according to Bouillon la Grange, when re- decoctions are made with the same portion of he last is always deepest coloured. It is precipi- ɔundantly by glue, carbonate of potash, and car- of ammonia. Lime-water throws down a pre- , at first blue, and afterwards buff-coloured. Sul- f iron throws down a very dark green precipitate. l separates white flakes. When evaporated to , a reddish brittle substance remains, which has bitter taste, and does not attract moisture from nosphere.

n alcohol is digested over this bark, it acquires ish yellow colour. The tincture is rendered by water. When evaporated, it leaves a bril- ellow substance of a very bitter taste, which t a moderate heat, and emits an aromatic o-

e experiments indicate the presence of tannin, rinciple, extractive, and gluten, in this bark.

Quercitron.

ark of quercus nigra.—This tree, to which the f *quercitron* has been given, grows spontaneously th America. Dr Bancroft discovered, about the 784, that the inner bark of this tree contains a uantity of colouring matter; and since that time, een very generally used by the dyers. To pre- for them, the epidermis (which contains a brown ng matter) is shaved off, and then the bark is in a mill. It separates partly into stringy fila- and partly into a fine light powder.

rcitron bark readily gives out its colouring mat-

* *Ann. de Chim.* liv. 290.

Book IV.

ter to water heated to the temperature of 100°. At that heat water dissolves about $\frac{1}{11}$th of the bark employed. The infusion has a yellowish brown colour, and is rendered lighter by acids, and darker by alkalies. Alum occasions a scanty precipitate of a deep yellow colour; muriate of tin a copious bright yellow precipitate; sulphate of iron a dark olive precipitate; and sulphate of copper a precipitate of a yellow colour, inclining to olive *. From these experiments it is obvious, that the colouring matter of this bark is a species of extractive. The other ingredients have not been examined.

Horse chesnut.

8. *Bark of the æsculus hippocastanum*—The bark of this tree, which forms so fine an ornament in parks and avenues, has lately been proposed in Paris as a remedy in intermittents, and a set of observations on it have been published by Mr Henry †. Water or moderately strong spirits are the best solvents of it. Strong alcohol dissolves but little. The watery infusion has a fawn colour and a bitter taste, without astringency. It is precipitated abundantly by gelatine, and sparingly by acids. It precipitates iron green. With nitrate of mercury it forms a copious precipitate. The infusion of nutgalls and tartar emetic produce no effect upon it. From these properties it is obvious that it differs entirely in its constituents from the different species of cinchonæ examined by Vauquelin.

Cinnamon.

9. *Cinnamon.*—This is the inner bark of the *laurus*

* Berthollet, *Elemens de l'Art de la Teinture*, ii. 262.

† *Ann. de Chim.* lxvii. 205.

nomum, a tree which grows chiefly in Ceylon, Chap. II.
it is cultivated for the bark.
is bark has a reddish brown colour, and consists
ng rolled pieces which breaks into splinters. It
very pleasant aromatic smell, and a pungent but
able taste. Its properties are owing entirely to
olatile oil which it contains. This oil may be
ated by infusing the bark in alcohol, and then
ating the alcohol from the oil by distillation. It has
tish yellow colour, and an extremely pungent taste
mell. The quantity yielded by cinnamon is very
. From 16 ounces of bark, Neumann obtained
two scruples and a half of oil. When water is dis-
off this bark, it comes over milky, from the ac-
anying oil, which it retains with great obstinacy;
little separating till the mixture has stood a very
derable time *.

SECT. V.

OF LEAVES.

e leaves of plants bear a greater resemblance to
other than any of the parts already treated of.
y are covered only with an epidermis; the cortical
ers of the bark being wanting. Below the epider-

* Neumann's *Chemistry*, p. 402.

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mis is a pulpy matter, usually green, which contains a resinous matter and a portion of gluten. Below this is the fibrous matter, or rather the vessels which form the outline of the leaf. Alcohol extracts the green colouring matter of leaves, and so do oils but not water. It is remarkable, that even those leaves which are not green still give a green tincture to alcohol. The green colour soon fades when exposed to air, either in solution, or separated by evaporation *. Many leaves give a yellow colour to cloth, which may be fixed by means of alum. Hence the much greater number of yellow dyes than of any other colour. The leaves of woad (*reseda luteola*) are those which give the finest yellow, and they are much employed by the dyers on that account.

No extensive series of chemical experiments having hitherto been made upon leaves in general, I must satisfy myself with noticing the few specimens which have been examined by chemists. The following are the most remarkable of these.

Senna.

1. *Senna*.—This drug, much used in medicine as a mild purgative, is composed of the leaves of *cassia senna*, a small shrub which grows chiefly in Egypt, from which country it is imported into Europe. It has been chemically examined by Bouillon la Grange.

The leaves are lanceolite, of a yellowish green colour, an aromatic and somewhat disagreeable odour, and a bitter taste. Steeped in water, senna communicates to that liquid its peculiar smell and taste, and a reddish brown colour. The strong mineral acids, ox-

* Lewis, Neumann's *Chemistry*, p. 434.

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cid, and the alkaline carbonates, throw down a
pitate ; so do barytes water, and the nitrates of mer-
silver, and lead. The infusion of galls strikes a
wish buff colour, and throws down a slight preci-
. Alcohol throws down a precipitate, which, if
lieve Bouillon la Grange, is composed of about
arts of carbonate of lime and one part of silica *.
esidual liquor contains extractive, with some salts,
bases are potash and magnesia.

en the infusion is exposed to the air, a substance
itates from it. A precipitate is obtained also by
uriatic acid. This precipitate is of a lemon yel-
olour, insoluble in water, has a bitter taste, dis-
in alcohol and alkalies, and, in short, possesses
aracters of resin.

e chief matter taken up from senna by water is a
ar extractive, which is converted into a species
in by the absorption of oxygen ; to this substance
alities of senna are owing. If we believe Bouil-
Grange, its activity depends upon its absorbing
n.

hundred parts of water boiled on senna are suffi-
o deprive it of all the soluble matter which water
able of extracting. Alkali separates from the re-
a portion of matter similar to the extractive, al-
by exposure to the air. The leaves are now green,
ive out a green matter to alcohol. This sub-

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do not clearly understand this part of the analysis. The preci-
stated to be partly soluble in water and alcohol, and yet to be
by alcohol. These characters surely do not apply to carbonate
and silica.

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stance is insoluble in water and alkalies, and is whitened by oxymuriatic acid, and rendered less soluble in alcohol. These properties indicate a peculiar substance. 244·6 parts of senna yield to these different menstrua 79·6 parts, or rather more than ⅓d of soluble matter. When the watery infusion of senna is evaporated to dryness, and the residue burnt, it yields potash, sulphate of potash, carbonate of lime, magnesia, and silica *.

Wormwood.

2. *Wormwood.*—This is the leaves, and likewise the stalks and flower-tops of the *artemisia absynthium*, a plant which grows wild in many parts of Britain. Wormwood has a strong smell, rather disagreeable, and an intensely bitter taste. Its smell is owing to a volatile oil which it contains. It contains, besides, a considerable portion of bitter principle. No late analysis of wormwood has been made. The last is that of Kunsmuller †, who obtained, by water, from 12 parts of wormwood, the following products:

Resin	0·48
Muriate of potash	0·12
Vegetable acid	0·50
Ditto combined with potash	2·14
	3·24

The residue, after the action of water, being burnt, left an ash, which, from 12 ounces of wormwood, contained the following substances:

* *Ann. de Chim.* xxvi. 3.

† Ibid. vi. 35.

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Muriate of potash	.	3 grains
Sulphate of potash	.	1
Carbonate of lime	.	59
Alumina	.	5
Sulphate of lime .	.	5
Silica	.	4
Oxide of iron . .	.	3

Tobacco.

3. *Tobacco*.—This substance is formed from the leaves of the *nicotiana tabacum*, a plant which is a native of Virginia, where it is cultivated very extensively for the purposes of commerce. Its name was given it from Tabaco, a province of Mexico, where it was first observed, and whence it was originally brought to Europe *.

Tobacco, when properly cured, has a yellowish green colour, a strong, and rather unpleasant smell, and a very acrid taste. When burnt it emits a strong odour, which to many is peculiarly grateful. When swallowed, it acts very violently upon the system ; and when taken in sufficient quantity, proves fatal. No exact chemical analysis of tobacco has been published ; though several of its constituents have been ascertained.

When distilled, it yields an oil of a very acrid and poisonous nature †. To this oil, which has a green colour, the peculiar properties of tobacco are at present ascribed. When long boiled, tobacco loses much of its virulence, owing probably to the dissipation of the oil, and the decoction acts merely as a mild aperient.

* For a detailed account of the culture and management of tobacco, see Tatham's Essay on its culture and commerce, published in 1800.

† Neumann's *Chem*. p. 356.

Book IV. When distilled with water or alcohol, no oil whatever is obtained.

When the juice of tobacco is evaporated to dryness, it leaves a reddish matter, of an acrid taste, which gives no colour to alcohol. Muriate of potash is present in it in considerable quantity *. Besides these substances, tobacco appears to contain a portion of bitter principle, some extractive, and a quantity of mucilaginous matter.

Asparagus. 4. *Asparagus*.—This plant has been lately analysed by Robiquet. I place the result here rather than any where else, because the whole plant was employed, and the leaves constitute the principal part of it.

M. Robiquet reduced the asparagus to the state of a pulp, and separated its juice by expression. A feculous matter was separated from this juice by filtration. Boiling alcohol dissolved a portion of this fecula, and left matter which possessed the properties of gluten. As the alcohol cooled, a portion of wax precipitated. The alcohol, by evaporation, left a green acrid matter, intermediate in its properties between resin and volatile oil.

The filtered juice had the appearance of whey, and reddened the infusion of litmus. When heated it deposited flakes, which were considered by Robiquet as albumen. When left for a long time to evaporate in the open air, a quantity of asparagin and of saccharine matter, having the appearance of manna, separated in crystals. The juice was inspissated, and treated with alcohol. A portion dissolved; the residue was dissolved in water.

The alcoholic solution, when treated with sulphuric

* Bouillon La Grange, *Jour. de Phys.* xxxix. 193.

acid, and distilled, yielded vinegar. When this solution was evaporated to dryness and burnt, the ashes consisted of potash, carbonate of lime, and phosphate of potash and of lime. Hence it was probable that the acetic acid was combined with potash and lime.

The watery solution reddened vegetable blues. The infusion of nutgalls throws down a precipitate from this solution. The residue contains a peculiar extractive matter and a colouring matter; and doubtless, also, asparagin and sugar.

Such is the result of Robiquet's very ingenious and interesting analysis of this substance *.

Aloes.

5. *Aloes*.—This is the inspissated juice of the leaves of a variety of the *aloe perfoliata*, a plant which grows in Socotora, an island in the East Indies. Aloes has a resinous appearance, a reddish yellow colour, a bitter taste, and an aromatic smell. It has been recently examined by Braconnot, who found it composed chiefly of a peculiar matter similar to that detected by Vauquelin in many febrifuge barks, and to which Broconnot proposes to give the name of *resinous, bitter principle* †. Trommsdorf, on the other hand, and Bouillon La Grange and Vogel, consider it as composed of resin and a peculiar extractive matter ‡. Fabroni has discovered, that the recent juice of the leaves of the aloe has the property of absorbing oxygen, and of assuming a fine reddish purple, and of yielding a pigment which he strongly recommends to the painter §.

6. *Atropa belladonna, deadly nightshade*. The leaves of this plant have been lately examined by Melandri,

* *Ann. de Chim.* lv. 152.

† Ibid. lxviii. 18.

‡ Ibid. p. 11. and 155.

§ Ibid. xxv. 301.

Book [illegible]

[illegible] of magnesia with excess o[illegible] [illegible] muriate of potash, a soft gree[illegible] [illegible], extractive, and a substance whic[illegible] [illegible] animal extractive, no doubt analogou[illegible] [illegible] albumen *.

[illegible] *palmatum*, *rhubarb*.—The leaves of thi[illegible] [illegible] lately examined by Bouillon La Grange[illegible] [illegible] them to contain a considerable quantity o[illegible] [illegible] of potash and of malic acid †.

[illegible] *tinctoria*, *woad*. The leaves of this plan[illegible] [illegible] lately been subjected to analysis by Chevreul[illegible] The expressed juice, separated by filtration from th[illegible] *green fecula*, with which it was mixed, deposited on [illegible] a blue powder, which possessed the properties of *indigo*. When heated, white flocks separated, consisting no doubt of *gluten*. When distilled, the liquid that came over yielded traces of a *volatile oil*, of [illegible], and of *sulphur*. When distilled with sulphuric acid, the liquid that came over contained *acetic acid* and *prussic acid*. Evaporated to dryness, and digested in alcohol, it yielded to that liquid a quantity of matter described in the last Chapter of this Work, under the section entitled *Of Indigo* by the name of *green matter*. It yielded also a yellow coloured *extractive*, and the following salts; *nitrate of potash*, *muriate of ammonia*, *acetate of potash*, *muriate of potash*, and pure *acetic acid*. The residue thus deprived of the substances soluble in alcohol consisted of *gum*, *yellow extractive*, *supermalate of lime*, *sulphate of lime*, and a salt which Chevreul considered as *citrate of lime-and-magnesia*.

* *Ann. de Chim.* lxv. 222.

ie green fecula being examined, was found to consist Chap. II.
green coloured resin, *wax*, *indigo*, *gluten*, and *woody re*. The dry matter of the leaves, from which the ice had been expressed, yielded *woody fibre*, *green in*, *wax*, *indigo*, *nitre*, a *red coloured matter*, *malate of ie*, and traces of some other salts *.

9. The leaves of the *indigofera anil*, examined by the me chemist, yielded the same products with the isatis, ut the quantity of indigo obtained was much greater †.

10. Besides the leaves enumerated in this Section, any others are employed in medicine, especially on he continent, where the Materia Medica includes a uch greater variety of articles than in Britain.

SECT. VI.

OF FLOWERS.

flowers of vegetables, on account of the great va- and beauty of their colour, attracted at an early the attention of dyers and painters; but, upon few have been found capable of yielding service- aterials for either of these artists. The blue d flowers, in general, readily give out their to water; though there are some from which

Blue flowers.

* *de Chim*. lxviii. 254. † Ibid. p. 305.
xxv. 301.

Book IV. water gains only a reddish or purplish hue. Scarcely any give a blue colour to alcohol: some give a red colour to that liquid, and some no colour whatever*. The expressed juice of most of these flowers is blue. This colour is changed into red by all acids, and into green by all alkalies and alkaline earths.

The nature of the colouring matter of these flowers is still unknown. But whatever it be, it is of a very perishable nature; for the flowers cannot be dried without losing their colour almost entirely. The more rapidly they are dried, and the more completely the air is excluded, the more of their colour they retain; but even after that, they mostly lose it altogether, and become white or yellow. The expressed juice gradually becomes purple, and soon fades altogether. Even when reddened by acids, these juices soon become purple, and at last colourless. The green colour induced by alkalies gradually changes to a yellow, which has some permanence †.

Red. The colour of the red flowers, in general, is scarcely more permanent than the blue. They all give out a red colour to water. The pale red and purple flowers scarcely tinge alcohol; resembling in this respect the blue flowers, to which indeed, in point of colouring matter, they seem to approach very nearly. The flowers, which have a full red colour, give a deep red tincture to alcohol; the pale red are tinged green by alkalies, and their red heightened by acids, like the blue flowers; but this is not the case with the full red flowers ‡.

* Lewis, Neumann's *Chem.* p. 430. † Lewis, Ibid. p. 431.
‡ Lewis, Ibid.

Chap. II.

Yellow.

The colour of the yellow flowers, whether pale or deep, is much more durable. They, in general, dry very well, and give out their colouring matter both to water and alcohol. When wool or silk is previously impregnated with alum and tartar, it receives a durable yellow colour when boiled with yellow flowers. Some of them, indeed, appear to be used by dyers for this purpose. Neither acids nor alkalies destroy the yellow colour of flowers, though both alter its shade; the acids rendering it paler, and the alkalies deeper. Alum likewise heightens the colour, though not so much as alkalies *.

White.

Even white flowers are by no means destitute of colouring matter. Many of them strike a green with alkalies, though acids do not turn them red. Some of them seem to contain the same colouring matter as yellow flowers. Thus the petals of the *convolvulus sepium*, though white, give a deep yellow or orange colour to water, which is rendered paler by acids, and heightened by alkalies and alum. The vapours of sulphurous acid do not alter white flowers, though they destroy the colour of all others †.

For these curious observations on the colours of flowers, we are indebted to Dr Lewis. Most of them contain a peculiar volatile oil, to which they owe their smell. Their other constituents remain still unknown, as few of them have been subjected to chemical analysis. The following are the species which have hitherto attracted the attention of chemists or artists:

Carthamus tinctorius.

1. *Flowers of the carthamus tinctorius.*—This is

* Lewis, Neumann's *Chem.* p. 431. † Ibid. p. 432.

Book IV. an annual plant, cultivated chiefly in Egypt for the sake of the flowers. The petals are originally of a fine red, but lose much of their colour on drying. It is from this substance that the *rouge*, or red pigment, employed by the ladies, is extracted. When the flowers have come to maturity, they are pulled, their juice expressed, the residue washed repeatedly with salt water, and exposed upon mats to dry. Care is taken to cover them from the action of the sun during the day, and to expose them to the action of the evening dews, in order to prevent them from drying too fast. In this state they are brought to Europe under the name of *safflower*, and the colouring matter is extracted from them by different artists. The process has been kept secret.

Beckmann published a very elaborate set of experiments on the flowers of the carthamus, in 1774 *. Little addition was made to our knowledge of this substance after that period, till 1804, when Dufour published an excellent analysis of it †; and his observations have been since confirmed by those of Marchais ‡.

Analysis. The flowers of the carthamus contain two colouring matters: a yellow, which is soluble in water, and has hitherto been applied to no use; and a red, which is employed by the dyers, &c. and which constitutes the pigment called *rouge*. The yellow colouring matter dissolves readily in water; but it is very difficult by that means to separate the whole of it. The method followed by Dufour was to put the carthamus in a linen cloth, and knead it continually between the fingers, while a streamlet of water dropt upon it. By

* In the *Gottingen Transactions* for that year.

† *Ann. de Chim.* xlviii. 283.

‡ Ibid. l. 73.

inuing this process, and then steeping it in water, sumed a fine red colour. The liquid which passed, being filtered to separate some portion of the carnus, and some impurities with which it was mixed, a yellow colour. When heated to about 145°, a ber of flakes formed in it, consisting of albumen, ther of gluten. These were separated by filtra- and the liquid evaporated to dryness. The ex- obtained had a yellow colour and a strong taste. er dissolved the whole of this extract, except a on of brown matter, which possesses the properties sin. The watery solution gives a red colour to able blues, and is precipitated abundantly by in- n of galls, but not by glue. Oxymuriatic acid oys the yellow colour, and renders it white. When orated to dryness, and treated with alcohol, a por- dissolves, and a portion remains undissolved. The le portion is chiefly extractive; the insoluble yel- olouring matter.

hen the residual carthamus is digested for a suffi- time in alcohol, that liquid assumes a brick red ur. When this alcoholic solution is sufficiently entrated by evaporation, a matter separates in s, which has the appearance of honey, and pos- s properties analogous to those of wax. Scarcely colouring matter could be procured from the alco- c solution.

Dufour, after various unsuccessful attempts to ob- the red colouring matter of carthamus in a sepa- e state, at last succeeded by the following process, nded on the strong attraction between the red matter d cotton. Having deprived the carthamus as much possible of its yellow colouring matter, by means of

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water, he macerated it for an hour in a weak solution of carbonate of soda. He then decanted off this solution, put into it a quantity of cotton, and then drop into it lemon juice, till the liquid acquired a fine cherry red colour. After standing 24 hours, the liquid lost its red colour, the whole colouring matter having united with the cotton and dyed it red. The cotton was taken out, and washed repeatedly in water, to separate any of the yellow colouring matter which might have adhered. It was then put into a very diluted solution of carbonate of soda. This alkali separated the colouring matter from the cotton, dissolved it, and assumed a yellow colour. The cotton being removed and lemon juice dropt into the solution, a fine rose-colour powder gradually separated, and at last precipitated. This was the red colouring matter.

From this process, we see that the red colouring matter has a stronger attraction for cotton than the yellow and that by means of cotton the two pigments may be separated. We see, too, that it is soluble in alkaline carbonates, but precipitated by acids. The alkalies dissolve it also but alter its nature. The solution of it in the alkaline carbonates is yellow. It is insoluble in water. Alcohol dissolves it readily, and assumes a fine rose red colour. When this tincture is heated, it assumes a shade of orange. It dissolves likewise in ether, but not well. The oils, both fixed and volatile, have no action on it. When distilled it yields very little water, scarcely any gases, a little oil, and a portion of charcoal equal to $\frac{1}{3}$d of its original weight. When this charcoal is burnt, no sensible portion of ashes remains behind. From these properties, for which, as well as for almost all the other facts respecting carth-

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a precipitate with glue, and does not alter the solution of tartar emetic. With sulphate of iron it strikes a deep green, which passes into black on drying. The mineral acids occasion brown precipitates, but the alkaline carbonates produce no change in it *.

When the flowers are macerated in alcohol, the liquid acquires a yellow colour. It reddens vegetable blues, strikes a green with sulphate of iron, and becomes milky when mixed with water. When this tincture is distilled, the alcohol which comes over has a bitter taste, but does not alter vegetable blues; while the liquid which remains in the retort is very acid, precipitates with water, and strikes a green with sulphate of iron. When evaporated to dryness, a bitter acid powder remains, seemingly of a peculiar nature †.

When distilled, the flowers of the arnica yield a yellowish acid liquor, which strikes a black with sulphate of iron. This liquid is covered by a quantity of oil. When these flowers are burnt, the residual ashes contain potash, carbonate of potash, muriate and sulphate of potash, and carbonate of potash ‡.

Saffron.

3. *Saffron.*—This yellow pigment is composed of the pistils of the *crocus sativus.* The flowers of this plant are of a purplish blue colour, but the upper part of the pistil is of a deep orange, and divided into three fleshy filaments. These are carefully picked out, dried, and pressed into cakes.

Saffron is in long broad filaments of a deep red colour without any yellow; moderately dry, yet flexible

* Bouillon la Grange, *Ann. de Chim.* lv. 38.
† Ibid. lv. 39.
‡ Ibid.

and soft, and difficultly reduced to powder. It has a strong agreeable smell, affecting the eyes, and drawing tears from them, and a pungent, and somewhat bitter taste *.

Hitherto saffron has not been subjected to a correct chemical analysis. From the experiments of Neumann, it does not appear that any volatile oil can be procured from it by distillation. It is probable, however, that it owes its strong smell to such a principle, though in too small a quantity to be easily obtained separate. The colouring matter of saffron is equally soluble in alcohol and water; and, if we believe Hermbstadt, is pure extractive.

SECT. VII.

OF POLLEN.

The antheræ of most vegetables, at the time that the flower is in perfection, is covered with a considerable quantity of a powdery matter, usually of a yellow colour, which, falling upon the pistil, is supposed to impregnate it. This matter is known by the name of *pollen*. In some plants, especially those in which the male and female flowers are separate, the quantity of it is so great, that it may easily be collected.

* Neumann, p. 401.

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Experiments of Lewis.

The first person who examined this powder was Dr Lewis; but in his time chemistry had not made sufficient progress to enable him to make a complete analysis. He found that alcohol, in which it is macerated, acquires a bright yellow colour, and that water takes a duller yellow, while the undissolved portion is of a yellowish white colour. The colour of these infusions is heightened by alkalies, and turned *red* by acids. When alkalies are dropt into the reddened solution, a deep yellow colour is restored *.

Fourcroy and Vauquelin have lately published a detailed analysis of the pollen of the *phœnix dactilifera*, or date tree, which may be considered as furnishing a pretty correct view of the properties of this class of vegetable substances. At least it is probable, that the pollen of different vegetables does not differ nearly so much from each other as the other parts of plants.

Pollen of the date tree.

The pollen of this tree is so abundant, that at the season of fructification, it surrounds the plants like thick dust. The specimen examined was brought from Egypt by Delille. Its colour was sulphur yellow, its taste was sourish and unpleasant, it reddened the infusion of litmus, and communicated to water a yellow colour, and a sensible degree of acidity. The watery infusion was precipitated by lime water and ammonia, by alcohol, and by some metallic salts.

Action of water and

When pollen was washed in cold water, that liquid acquired a reddish brown colour, a sourish taste and smell, not unlike that of beer. When evaporated, the liquid left a reddish brown matter, which had the con-

* Neumann's Chem. p. 238.

tence and odour of melasses; its taste was acid, but sagreeable. Cold alcohol produced no effect upon is matter, but by the assistance of heat it dissolved a ortion of it, and assumed a dark colour. The residue d more consistence, and was less coloured. It dis-lved with facility in water, allowing at the same time greyish bulky matter to separate. Thus the matter ken up by the watery infusion from pollen has been vided into three portions.

Chap. II.
Alcohol.

The alcoholic solution being concentrated by evapo-tion to the consistence of an extract, had a red colour, e odour of baked apples, and a taste strongly acid, t disagreeable. It presented all the characters of alic acid. The grey matter, which refused to dis-lve in water, possessed the properties of phosphate of me.

The aqueous solution was ascertained to consist hiefly of phosphate of magnesia, malic acid, and an nimal matter, which formed a copious precipitate with he infusion of nutgalls.

Insoluble parts.

The pollen, thus deprived of its soluble matter, be-ing exposed on filtering paper to the open air for a week, instead of drying assumed the form of a paste, and ran rapidly to putrefaction, emitting an odour si-milar to that of old cheese. When dried, this matter became semitransparent, and of a consistence resem-bling that of glue. Before being dried it mixed rea-dily with water, and exhibited the characters of soap. The fixed alkalies showed the presence of ammonia in t. When distilled there came over a watery liquid, which gradually became coloured as the distillation dvanced: some time after there came over a red co-oured oil and carbonate of ammonia, partly in crystals,

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and partly in solution. The liquid also contained a portion of the oil in the state of a soap. The charcoal left was voluminous, and difficult of incineration. When burnt it left a considerable portion of phosphate of lime.

Action of acids.

The pollen is partly soluble in muriatic acid. The nitric acid reduces it to a paste, azotic gas is disengaged and afterwards, on the application of heat, nitrous gas and carbonic acid. A yellowish oil separated and swam upon the surface, and alkalies separated earthy phosphates and oxalates. When the liquid was evaporated to dryness, it left a yellowish red matter, extremely bitter, tenacious, and adhesive, and perfectly soluble in water. This matter, from the description of it, must have been a species of artificial tannin. Thus it appears, that by the action of nitric acid, the portion of the pollen which is insoluble in water is converted into oil and artificial tannin. The oily matter became solid on cooling, and possessed almost exactly the properties of tallow treated with nitric acid.

Strong alkaline leys dissolve the pollen, and assume with it the properties of soap, while ammonia is disengaged.

When the pollen, mixed with water, is set aside to ferment, it disengages the odour of new cheese, and assumes the form of a tenacious mass. Its taste is extremely sharp; it contains abundance of ammonia, partly united to oil, and partly to malic acid. From all these phenomena, there is reason to believe that the insoluble part of the pollen approaches vegetable gluten in its properties; or rather, that it is intermediate between gluten and albumen.

Such are the properties and constituents of the pollen

of the date tree, as far as they have been ascertained by Fourcroy and Vauquelin *. We may conclude from them, that it approaches very much to the nature of animal matter. Chap. II.

Professor Link has lately examined the pollen of the hazle nut. It differs a good deal from that of the date tree just described. He found in it tannin in great abundance, a resin, a good deal of gluten, and a little fibrin †.

SECT. VIII.

OF SEEDS.

THE seeds of vegetables, constituting one of the most important articles of food, and being the materials from which a variety of useful substances are procured, have been more subjected to chemical experiments than any of the other parts of plants.

Constituents. They all contain a considerable portion of starch, though this matter differs somewhat in its properties in different seeds. Gluten is likewise a common ingredient, but extremely various both in its quantity and in its appearance. Some seeds contain a saccharine matter, as those of the *lycopodium*; but the quantity is always small, and its properties are hardly ever the same as

* *Ann. de Mus. d'Hist. Nat.* i. 417. † *Ann. de Chim.* lxii. 292.

Book IV. those of true sugar. Fixed oil is also a common ingredient. In the seeds of the grasses, the proportion of it, if any can be detected, is always small: the same remark applies to the seeds of the papileonaceous plants; but the seeds of the cruciform plants abound in a limpid and nearly insipid oil. In some seeds a volatile oil is present, but this is not common. Some possess a peculiar colouring matter; some possess a portion of bitter principle, as the seeds of the common broom and of the coffee plant.

Saussure junior has lately shown that wheat, and probably every other kind of corn, yields a quantity of phosphorus, if it be charred in a moderate heat, and the charcoal be afterwards violently heated in a porcelain retort. He has shown that the phosphorus, in this case, is owing to the decomposition of phosphate of potash, which exists in these seeds, and which is decomposed by the charcoal at a very high temperature. He has shown that phosphate of soda, and even phosphate of lime, may be decomposed in the same way *. Thus the observations of Margraf, and some of the earlier chemists, respecting the phosphorus which may be obtained from the seeds of plants, have been verified.

I shall in this Section enumerate, in the first place, the properties of those seeds which are known by the name of *corn*, and are used as articles of food; then the seeds of the papileonaceous plants; namely, peas, beans, vetches, &c. which are likewise employed as food. The seeds of the remaining tribes of plants have been hitherto but imperfectly examined; we can only there-

* *Ann. de Chim.* lxv. 189.

fore detail the experiments hitherto made, without any attempt at arrangement. Chap. II.

The most important genera of corn are, wheat, rye, oats, barley, rice.

1. Wheat, the *triticum hybernum* (and other species) of botanists, has been cultivated from time immemorial in Europe and the northern parts of Africa, and the seeds of it employed as one of the most important articles of food. Indeed wheat flour is the only substance known from which good loaf bread can be made. The seeds, when ripe, are ground to a fine powder, and by passing this powder through cloth sieves, of various degrees of fineness, it is separated into distinct portions. The fine flour constitutes the greatest portion; and the *bran*, which consists of the outer coat of the seed, and which is the coarsest of all, constitutes the next greatest portion. Wheat.

Hitherto the flour of wheat only has been subjected to a chemical examination; while the bran, which may vary from one-third to one-fourth, has been neglected. The two most remarkable substances in wheat flour are the *starch*, which constitutes by far the greatest part of it, and the *gluten*, which is the next ingredient in point of quantity. It appears also, from my trials, to contain a small portion of *bitter principle*. Saccharine matter exists in it also, though in a very small proportion. Mucilage is mentioned as a constituent by Fourcroy and Vauquelin; and from their experiments, also, it appears that phosphate of lime is present, but that they did not detect any phosphate of potash *. Constituents.

* *Ann. de Mus. d'Hist. Nat.* No. xxxvii. p. 3.

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Water in which wheat flour has been macerated for six hours, has an opal colour, and becomes transparent very slowly. Its taste is sweetish, it has the odour of unripe grain, and does not alter vegetable blues. The infusion of nutgalls, oxymuriatic acid, and other acids, occasion a precipitate in it. It becomes very rapidly sour. When heated, yellowish flakes are separated. When concentrated by evaporation, its taste becomes more perceptibly sweet. When inspissated sufficiently, it assumes a golden yellow colour; has a sweet taste, but is, at the same time, acid and acrid; yellowish flakes separate, and a crust of phosphate of lime coats the capsule in which the evaporation is performed. Alcohol coagulates it, and throws down a substance which possesses the properties of gluten. Hence it is evident, that the water owes its properties to the gluten which it holds in solution *, and probably also to a little bitter principle. It contained also some sugar and mucilage, and phosphate of lime.

Rye.

2. Rye is the seed of the *secale cereale*, a plant cultivated in the northern parts of Europe, in considerable quantity, as an article of food. Bread made of it is much denser than wheaten bread, and has a brownish colour, and a peculiar sweetish taste, which to most persons is rather agreeable. We are indebted to Einhof for an elaborate analysis of rye-meal. He published the result of his experiments in the summer of 1805 †.

Soluble part;

A determinate portion of rye-meal was formed into a paste, washed in pure water till that liquid ceased to

* Fourcroy and Vauquelin, Ibid.

† Gehlen's *Jour.* v. 131.

acquire any colour, or to take up any thing. The liquid, after filtration, had a yellowish colour, an insipid taste, and a smell like that of new whey. It slightly reddened litmus paper, and was rendered muddy by carbonate of potash, sulphate of silver, and infusion of galls. When raised to the boiling temperature, it became muddy, and a number of white flakes separated. These, when collected and edulcorated, had the appearance of curd. They dissolved in alkaline leys, were insoluble in alcohol, and possessed the properties of *vegetable albumen*. When the liquid was concentrated by evaporation, it deposited a small additional portion of albumen. This being separated, the liquid was evaporated to the consistence of honey, and digested in alcohol repeatedly till nothing more was taken up. The residue was greyish white and insipid: water dissolved it slowly, and the solution, being evaporated, deposited more flakes of albumen. The residue had the appearance of a solution of gum arabic, and when evaporated to dryness, left behind it a portion of gummy matter.

The alcoholic solution became muddy when mixed with water. The alcohol being drawn off by distillation, there remained in the retort an aqueous solution, of a wine yellow colour, with large brownish flakes swimming in it. These flakes, when collected, were found to possess the properties of gluten. They formed a glutinous mass with cold water, the bulk of which contracted when the water was made to boil. Boiling alcohol dissolved it; but ether took up only the colouring matter. Alkalies dissolved it, and acids threw it down again from its solution.

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The watery solution, thus freed from the gluten, being evaporated, left an extract of a wine yellow colour. By repeated digestions in alcohol, dilutions with water, and evaporations, it was freed from a portion of gluten, which still adhered to it. Its taste was then sweet, but harsh; its colour wine yellow; and it was soluble in water, alcohol, and ether. It was considered as the saccharine matter of rye.

Insoluble.

The rye-meal, thus freed from the matters soluble in water, was mixed with a great quantity of water, and by repeatedly agitating the liquid, and decanting it off after standing some time, it was separated into two portions; namely, a greyish coloured substance, which, being lightest, did not so soon subside, and a white powder, which possessed the properties of starch. The grey coloured substance, by repeated digestions in alcohol and water, was separated into three portions; namely, gluten, starch, and the coats of the rye-seeds. Such are the constituents of rye-meal, according to Einhoff. The following are the proportions of these different substances, detected by this chemist, in the best rye-seeds and rye-meal. 3840 parts of good rye-seeds were composed of

Constituents.

930 husk
390 moisture
2520 pure meal

3840

The same quantity of good rye-meal contained

Chap. II.

126	albumen
364	gluten, not dried
426	mucilage
2345	starch
126	saccharine matter
245	husk
208	loss
3840	

But the proportion of these substances must vary extremely according to the soil, the climate, and the age of the rye. The gluten of rye differs in several particulars from that of wheat. It is less tenacious and more soluble. When it was allowed to ferment, Einhof perceived a strong smell of nitric acid, which is peculiar to this species of gluten. The starch of rye bears a striking resemblance to that of wheat. Like this last, it does not form a colourless solution with boiling water, and always precipitates at last, when the solution is left a sufficient time at rest.

Ashes.

Einhof did not examine the ashes of rye; but from the experiments of Schræder, we know that the same quantity, analysed by Einhof, namely 3840, yielded the following fixed substances*:

3·90	silica
3·35	carbonate of lime
3·55	carbonate of magnesia
0·35	alumina
0·80	oxide of manganese
0·22	oxide of iron
12·17	

* Gehlen's *Jour.* iii. 525.

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Oats.

3. Oats are the seeds of the *avena sativa*, a plant cultivated in considerable quantities as an article of food. No correct chemical analysis of this seed has yet been made. The husk is uncommonly thick, and constitutes a considerable portion of the corn. The proportion of starch is likewise considerable, though it is difficult to free it from another substance with which it is united.

Barley.

4. Barley is the seed of the *hordeum vulgare*, a plant too well known to require any description. Great crops of it are reared annually, partly as an article of food, and partly as a material from which malt liquors and ardent spirits are drawn. This species of corn has been examined of late with considerable attention by chemists, partly in order to form correct conceptions, if possible, of the nature of the process of fermentation, and partly to ascertain the constituents of barley. Fourcroy and Vauquelin published several ingenious remarks and experiments on it in 1806 *, and Einhof published a still more elaborate analysis about the commencement of the same year; having examined this grain in different stages of its growth, and after it was fully ripe †.

Unripe barley.

When unripe barley-corns are triturated with water, the liquid acquires a milky colour. If this process be continued, adding fresh portions of water as long as the liquid passes off muddy, there remains only a green husky matter. When this matter is macerated a sufficient time in cold water, it acquires a greenish grey colour, and when dry has the appearance of vegetable

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* *Ann. de Mus. d'Hist. Nat* No. xxxvii. p. 5.

† Gehlen's *Jour*. vi. 62.

ore. The water in which it was macerated, when oiled, deposites a few flakes of albumen, and when vaporated to dryness leaves a small portion of extractive.

The water with which the barley was at first triturated is at first milky, and gradually deposites a white powder; yet it does not become transparent, though allowed to stand a considerable time. When filtered, it passes through transparent, while a slimy substance of a greenish grey colour remains upon the filter. This substance possesses the properties of gluten. When the solution, now transparent and of a yellowish colour, is boiled, it deposites flakes of albumen. It reddens litmus paper, and is strongly precipitated by lime-water, nitrate of lead, and sulphate of iron, indicating the presence of phosphoric salts.

The liquid being evaporated to the consistence of a syrup, and the residue treated with alcohol, the solution diluted with water, and the alcohol distilled off, to separate some gluten which still remained, a syrupy matter was obtained, having a sweet taste, which was considered as a saccharine matter of the barley. A portion refused to dissolve in alcohol. This portion was considered as extractive.

The white powder which precipitated from the water in which the barley had been originally triturated, possessed the properties of starch.

Such are the constituents of unripe barley, according to the experiments of Einhof. The following are the proportions of each which he obtained from 2880 parts of unripe barley *.

* Gehlen, vi. 83.

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Green husk, &c.	478
Albumen, with phosphate of lime	13
Gluten	52
Saccharine matter	160
Extractive	76
Starch	420
Volatile matter	1500
Loss	182
	2880

Ripe barley.

When ripe barley is steeped in water a sufficient time, and then cautiously kneaded between the fingers in a cloth, every part of the grain is washed away except the husk, which by this process may be dried and weighed.

When barley meal, previously made into a paste, is treated in the same way, a brownish residuum remains, consisting chiefly of the husk, though it contains also portions of starch and gluten which cannot well be separated. The water in which the meal has been washed gradually deposites a white powder, but does not become transparent though left at rest. It runs very soon into acidity. Indeed, if we believe Fourcroy and Vauquelin, barley often contains an acid; the water in which it has been macerated reddening the infusion of litmus: this acid is the acetic. The colour of this water is reddish brown. In holds in solution a considerable portion of matter, which, according to Fourcroy and Vauquelin, consists chiefly of gluten, but which Einhof found to be of a more complicated nature, consisting of albumen, or rather gluten, mucilage, and saccharine matter. It contains in solution likewise a notable portion of phosphate of lime.

Chap. II.

When barley meal is macerated a sufficient time in alcohol, that liquid acquires a yellow colour, and becomes muddy and more odorous, and by evaporation it an oily matter of a yellow colour and an acrid taste, having the consistence of butter. This oil burns like a fat oil, and forms soap with alkalies. It is but imperfectly soluble in alcohol *. This oil escaped the observation of Einhof. I obtained it by a process similar to that afterwards described by Fourcroy and Vauquelin; but its colour was asparagus green, and it did not burn with the same readiness as an oil. It has very much the appearance of olive oil coagulated, but its consistence is less, and its colour is darker. To this oil the peculiar flavour of spirits from raw grain is ascribed at present. If this opinion be well founded, the oil must be dissipated or destroyed by the process of malting.

Constituents.

The following are the proportions of the constituents obtained by Einhof from 3840 parts of barley-corns:

Volatile matter......	430
Husk..............	720
Meal.............	2690
Total	3840

From the same quantity of barley meal he obtained

* Fourcroy and Vauquelin, *Ann. de Mus. d'Hist. Nat.* No. xxxvii. p. 8.

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Volatile matter	36[illegible]
Albumen	[illegible]
Saccharine matter	200
Mucilage	176
Phosphate of lime, with some albumen . .	9
Gluten	135
Husk, with some gluten and starch . . .	260
Starch, not quite free from gluten . . .	2580
Loss	76
Total	8840

Besides these substances, Fourcroy and Vauquelin ascertained the presence of phosphates of lime and magnesia, and of silica and iron; and I found in it, besides these substances, phosphate of potash and nitrate of soda. The presence of phosphate of potash was ascertained likewise by Saussure junior.

Rice. 5. Rice, the seeds of the *orysa sativa*, ought to be considered here, on account of the striking resemblance which it bears to barley in its properties; but hitherto this important grain, almost the sole food of a great proportion of the human race, has not been subjected to chemical analysis. We may conclude from analogy, that its constituents are pretty much the same as those of barley.

Mais. 6. Mais. This is the seed of the *zea mais*, or indian corn. Some experiments on it have been made by Proust. It is converted into charcoal in the usual way, and leaves about $\frac{1}{7}$th its weight of charcoal. This charcoal is extremely difficult of incineration. It contains some phosphate of potash *.

* Nicholson's *Jour.* xviii. 239.

ing now given an account of the constituents of rious species of corn hitherto subjected to chemi- amination, let us proceed to the seeds of the pa- iceous plants. The most remarkable of these is, beans, kidney beans, lupines, lentiles, &c. Chap. II.

Peas. The seeds of the *pisum sativum* constitute a ommon and nutritive article of food. They have ately examined in different states by Einhof *, has devoted his chief attention to this peculiar of chemical investigation.

Green plant.

treating the green plant nearly in a similar man- th barley, he obtained from 3840 parts the fol- g constituents :

Volatile matter	3000
Starch	53
Vegetable fibre	400
Gluten †	70
Albumen	35
Phosphate of lime	4
Saccharine matter	176
Extractive	25
Loss	77
	3840

Pod.

green pod or husk of the pea, by a similar treat- yielded, from 3840 parts ‡,

* Gehlen's *Jour.* vi. 115.

† In the same state as that from the leaves of plants, and mixed with colouring matter.

‡ Gehlen's *Jour.* vi. 119.

Volatile matter	3120
Vegetable fibre	344
Starch	90
Green gluten	22
Albumen	$17\frac{1}{2}$
Phosphate of lime . . .	$3\frac{1}{2}$
Saccharine syrup	182
Loss	61
	3840

Peas. The peas themselves, when very young, are often filled with a sweet juice, which may be obtained by a slight pressure. Einhof examined this liquid. It has a greenish yellow colour and a very sweet taste. When exposed to the air, thin cuticles formed on its surface, and white flakes precipitated. It gradually underwent a kind of fermentation and became sour. From 1440 parts of this juice, Einhof obtained, by analysis *,

Albumen	10
Extractive	18
Saccharine syrup . .	165

This syrup had much the taste of raw sugar, but could not be made to crystallize.

Ripe peas. From ripe peas, by macerating them in water, and employing a mode of analysis similar to that used for ascertaining the constituents of barley, Einhof obtained the following products. The quantity employed was 3840 parts †.

* Gehlen's *Jour.* vi. 120. † Ibid. p. 13.

Volatile matter	540
Starchy fibrous matter, with the coats of the peas	840
Starch	1265
Animo-vegetable matter	559
Albumen	66
Saccharine matter	81
Mucilage	249
Earthy phosphates	11
Loss	229
	3840

Starchy fibrous matter.

The second of these constituents, entitled *starchy fi-ous matter*, was what remained after the peas, reduced a pulp with water in a mortar, had been washed ith water till they ceased to discolour it, or to give ut any soluble matter to it. This residue was in part omposed of the coats of the peas, and partly of a white brous matter without taste or smell. When dried, it ecame yellowish, and was easily reduced to powder; nd the powder formed a paste with water, and dis-olved like starch in hot water. It then bore a certain esemblance to starch, and agreed in its properties with he fibrous matter of potatoes *.

Animo-vegetable matter.

The fourth of the preceding constituents, entitled *ani-no-vegetable matter*, was obtained in this manner: The nilky water in which the peas had been macerated, af-er depositing the starch, still continued muddy, but either deposited any thing, nor would pass through the lter; but when diluted with its own bulk of water,

* Gehlen's *Jour*. vi. 123.

of this substance, as far as they have been ascertained by M. Einhof*. Chap. II.

When 3840 parts of ripe peas were reduced to ashes, the residue weighed 112 parts. From these ashes Einhof extracted phosphoric acid, sulphuric acid, muriatic acid, alumina, silica, carbonate of lime, phosphate of lime, oxide of iron, and phosphate of ammonia and magnesia†.

8. The seeds of the *vicia faba*, a small bean, becoming blackish when ripe, and used as an article of food, have likewise been examined by Einhof. The analysis was conducted in the same way as his other experiments already described. From 3840 parts of the ripe beans he obtained the following substances: Marsh bean.

Volatile matter	600
Skins	386
Starchy fibrous matter	610
Starch	1312
Vegeto-animal matter	417
Albumen	31
Extractive, soluble in alcohol	136
Gummy matter	177
Earthy phosphate	37½
Loss	133½
	3840‡

Fourcroy and Vauquelin, who made experiments upon this substance likewise, found the ashes which it leaves, when incinerated, to consist of the phosphates

* Gehlen's *Jour.* vi. p. 124. † Ibid. p. 132.
‡ Ibid. p. 136.

Book IV.

of lime, magnesia, potash, and iron, and of uncombined potash. They could detect no sugar in it *.

Kidney beans.

9. Kidney beans, which are the seeds of *phaseolus vulgaris*, have been likewise analysed by Einhof. They are characterized by the great proportion of animo-vegetable matter which they contain. From 3840 parts of these beans Einhof obtained the following substances:

Skins	288
Starchy fibrous matter	425
Starch	1380
Animo-vegetable matter, not quite free from starch	790
Extractive	131
Albumen, with some vegeto-animal matter	52
Mucilage	744
Loss	21
	3840†

Lentiles.

10. Lentiles. To the same indefatigable chemist we are indebted for the analysis of the seeds of the *ervum lens*. From 3840 parts he obtained the following substances:

Fibrous matter	720
Albumen	44
Earthy phosphates, with a little albumen	22
Extractive, soluble in alcohol	120
Gummy matter	230
Starch	1260
Vegeto-animal matter	1433
Loss	11
	3840 ‡

* *Ann. de Mus. d' Hist. Nat.* No. xxxvii. 9. † Gehlen's *Jour.* vi. 545.
‡ Ibid. p. 5[illegible]

Here the proportion of animo-vegetable matter is still greater than in the kidney bean. Chap. II.

Lentiles were examined by Fourcroy and Vauquelin; but whether the same species as the preceding they do not put it in our power to determine, as they omit the botanical name. The liquid in which the flour of these seeds was macerated was not acid: it had a slight and rather disagreeable taste, and was precipitated copiously by infusion of galls, oxymuriatic acid, and sulphate of iron. In short, it exhibited nearly the same phenomena as are described by Einhof. When the flour of lentiles is digested in alcohol, the liquid assumes a greenish yellow colour, and a bitter acrid taste. When distilled, it has the odour of vanilla very strongly, but acquires a disagreeable smell when mixed with water. The residue is greenish yellow, has the appearance of a thick solution of soap, and a green oil swims upon the surface. The pod of the lentiles contains a portion of tannin *.

White lupine.

11. White lupine. To Fourcroy and Vauquelin we are indebted for the analysis of the seeds of the *lupinus albus*; the farina of which, according to their experiments, differs from that of all the other liguminous plants hitherto tried, as it contains neither starch nor saccharine matter. They found in it a yellowish green oil of an acrid nature, which approaches the fixed oils in its properties; a vegeto-animal matter, which appears to bear a strong resemblance to gluten; a considerable portion of phosphate of lime and magnesia, and traces of phosphates of potash and of iron †.

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* *Ann. de Mus. d'Hist. Nat.* No. xxxvii. p. 10.

† Ibid. p. 12.

[illegible] These seeds have been lately [illegible] examination by Bucholz. The [illegible] the results which he obtained.

[illegible] hemp-seed yielded by expression [illegible] parts of a yellow coloured oil. [illegible] possessed all the characters of [illegible]. From the residue he procured, by di[illegible] coagulation by heat, about 3½ [illegible] quite half a part of fibrous [illegible] coats and husks of the seeds [illegible]. About one-fourth of a part of a [illegible] was obtained by means of alco[illegible] quantity of a substance to [illegible] the name of *mucilaginous sugar*, [illegible] about 1½ part of *gummy extrac*[illegible]

[illegible] This is the seeds of the *coffea arabica*, [illegible] usually of a small size. It was ori[illegible] from Arabia, and was unknown in [illegible]. The entire fruit has some resem[illegible]. Under a pulpy skin it contains an [illegible] which separates longitudinally into two [illegible] covered with a thin coat, and marked longi[illegible] with a furrow on the flat side, where they are [illegible]. The ripe fruit is dried in the sun, and heavy [illegible] over it, by which the seeds are parted [illegible] broken. They are afterwards separated by winnowing.

[illegible] experiments have been made by chemists to

* Gehlen's *Jour.* vi. 615.

Neumann's *Chemistry*, p. 378.

ascertain the constituents and qualities of coffee; Neumann, Geoffroy, Dufour, Kruger, Westfield, &c. published successively the result of their trials on it. The latest analyses are those of Hermann * and Cadet †. They neither agree well with each other, nor with those of preceding writers. It is probable that these differences ought to be ascribed partly to the different mode of analysis followed, and partly to variations in the berries examined.

Infusion.

The infusion of coffee in boiling water is of a yellowish green colour; but the decoction, by continuing the boiling, becomes brown. It becomes turbid on cooling. The alkalies render it more brown. It strikes a black with sulphate of iron, but does not precipitate with glue. Oxymuriatic acid nearly destroys the colour; but if an alkali be added the liquid becomes red. Cadet obtained a decoction with coffee which produced no effect upon vegetable blues; but other chemists describe it as changing them to red, and Hermann obtained with alcohol a solution which produced the same effect.

When water was distilled from coffee, what came over had an aromatic odour, and a few drops of a substance similar to myrtle wax swam on the surface of it; the residual liquid became milky when mixed with alcohol, and let fall a substance possessing the properties of gum.

When alcohol is digested on coffee, it acquires some colour. The solution when mixed with water becomes

* Crell's *Annals*, 1800, ii. 108.
† *Ann. de Chim.* lviii. 266.

... resinous matter. The ... leaves a substance ... and partly of the bitter ... From these expe- ... we see that coffee con- ... oil, gallic acid, mu- ... principle. It contains also, ... alumina, lime, muriate ... which separates from ... The result of Ca- ... as follows. Sixty-four

... extract and bitter principle
... acid
...
... insoluble matter

...

... loss

... 1920 parts of Levant and Mar- ... following proportions respective-

	Levant.	Martinique.
[illegible]	74	68
[illegible]	320	310
[illegible]	130	144
[illegible] matter	1335	1386
[illegible]	61	12
	1920	1920

Chap. II.

Roasted coffee.

When coffee is roasted, a portion of tannin is formed in it by the action of the heat. It appears also that a new substance, having a peculiar agreeable smell, is developed; but the nature of this new principle has not yet been ascertained. It is developed also by roasting barley, beans, and a great variety of other vegetables, which are on that account occasionally employed as substitutes for coffee.

An elaborate analysis of coffee has lately been published by Payssé. He examined with particular care the bitter principle of coffee, first pointed out by Chenevix, and has endeavoured to show that it is in reality a peculiar acid, to which he has given the name of *coffic acid*. It reddens vegetable blues, but in other respects does not seem better entitled to the name of acid than *tannin*. He detected in coffee, besides this substance, a quantity of albumen, resin, and extractive. It contains a great proportion of matter insoluble in water. Its ashes yield muriate of potash and carbonate of lime. Payssé could not succeed in ascertaining the presence of tannin in roasted coffee. When coffee is distilled it yields, according to him, an acidulous water, a thick brown oil, and carbonate of ammonia. Very little gaseous matter was obtained *.

Coco.

14. Coco. This is the fruit of the *cocos nucifera*, one of the most valuable vegetable productions of India. A detailed account of the management and products of this tree have been published by Le Goux de Flaix †; but we are still unacquainted both with the

* *Ann. de Chim.* lix. 196.

† *Phil. Mag.* xx. 316; and xxi. 77, and 120.

constituents and chemical properties of the nuts. The outer coat is fibrous, and formed by the natives into excellent cordage. The kernel contains a considerable proportion of fixed oil, used by the Indians for lamps *.

Almonds. 15. Almonds. This is the fruit of the *amygdalus communis*, used both as an article of food and in medicine. There are two kinds, the *bitter* and *sweet*. The latter consists chiefly of fixed oil and starch, or albumen; chemists have not yet ascertained correctly which. Bitter almonds, besides these two substances, probably contain also a portion of bitter principle. Prussic acid is likewise a constituent of them; but hitherto almonds have not been subjected to a regular chemical analysis.

Nutmeg. 16. Nutmeg. This is the seed of the *myristica moschata*, a tree which is cultivated in the Asiatic islands. The covering of the nut is known by the name of *mace*. The nutmeg varies in size and figure; it is furrowed on the outside, and greyish brown internally. Those that want white streaks are the best. From the experiments of Neumann, we learn that this substance contains two species of oil; a volatile oil, to which it owes its peculiar smell and taste, and which in his trials amounted to about $\frac{1}{16}$d part of the nut; and a solid fixed oil resembling wax, and amounting to about $\frac{1}{3}$d of the nutmeg. He detected also a quantity of gum †; and it is probable, from the appearance of the kernel, that it contains likewise starch. By expression, the solid oil is separated, and mixed with the volatile oil. In that state it is sold under the name of *oil of mace*.

* See Turner's *Indian Recreations*, ii. 282.
† Neumann's *Chem.* p. 424.

17. Pepper. This is the seed of the *piper nigrum*, a shrub cultivated in India for the sake of its berries. Its outer coat is of a dark brown colour; when deprived of it, the berry is known by the name of *white pepper*. Chap. II. Pepper.

Pepper, when macerated in cold water, does not lose its shrivelled appearance. The infusion acquires a brown colour, reddens vegetable blues, and has both the taste and odour of pepper. If we repeat the maceration a number of times, the liquid still continues to acquire a colour, but it ceases to have the smell and flavour of pepper. White pepper does not communicate any colour to water. Hence the colouring matter must reside in the outer coat. It possesses most of the properties of extractive. When pepper is macerated in alcohol, the liquid acquires a light yellowish green colour. When distilled, it leaves a green coloured matter, partly resinous, and partly oily. This oil is the source of the odour and taste of pepper. Its taste is extremely hot, and its smell, when dissolved in alcohol, and diluted with water, extremely pleasant. It possesses nearly the properties of volatile oil. When water is boiled for some time with ground pepper, it acquires the property of forming, with the infusion of nutgalls, a precipitate, which dissolves again when the liquid is heated to 120°. Hence it contains a portion of starch. These three substances, starch, oil, and extractive, are the most remarkable of the constituents of pepper *.

18. Anatto. This pigment is obtained from the seeds of the *bixa orellana*, a tree cultivated in Guiana and Anatto.

* See Nicholson's *Jour.* ii. 7

[illegible] parts of the West Indies. When ripe, the capsules are gathered, and the seeds being separated, are pounded, steeped in water for weeks or months, then subjected to the press; and the colouring matter thus obtained is suffered to subside, collected, and dried. A better process has been lately proposed by Leblond. The colouring matter, which is confined to the surface of the seeds, is separated by maceration and washing, and then thrown down from the water by an acid*. [illegible] in hard cakes, brown without, and [illegible] It dissolves much more easily in alcohol [illegible] Weak alkaline leys dissolve it likewise [illegible]. The decoction of anatto has a pe[illegible] a disagreeable taste. Its colour is [illegible] alkalies render it orange yellow; and [illegible] the acids throw down an orange-[illegible]. The chemical nature of this [illegible] not been ascertained, though it [illegible] be intermediate between extractive and [illegible]

[illegible] of the *phytolacca decandra*. These ber[illegible] purple colour to water, of a very [illegible]. A few drops of lime water change it [illegible] and this yellow liquid is the most delicate [illegible] hitherto observed. The smallest quantity [illegible] restores its purple colour. Braconnot, to whom [illegible] for these observations, has shown, that [illegible] times as delicate as the infusion of litmus. Unfortunately it alters its nature in a few hours,

* [illegible] 113.

† [illegible] *l'Art de la Teinture*, ii. 268.

and then loses its delicacy as a reactive. It can only be used when recently prepared *. Chap. II.

20. The seeds of the *lycopodium clavatum*, or common club moss, have been long remarkable for their combustibility. They are extremely small; and when blown into the flame of a candle they take fire, with a small explosion, and are used in theatres to imitate the appearance of lightning. They have been lately subjected to chemical analysis by Bucholz. From 1000 parts of the seeds he obtained 60 parts of a fixed oil, soluble in alcohol like castor oil; 30 parts of sugar; 15 of a mucilaginous extract. There remained a matter insoluble in water, alcohol, ether, oil of turpentine, and alkaline leys. But when boiled with the last of these agents, ammonia was disengaged, and a kind of extract formed. When 2000 grains of this substance were distilled, they yielded 290 ounce measures of gas, which was a mixture of carbureted hydrogen and carbonic acid; 1080 grains of a brownish oil, containing ammonia; 330 grains of a watery liquid, holding acetate of ammonia in solution. The residue in the retort, amounting to 310 parts, had very much the appearance of anthracolite. When the insoluble part of the seeds was boiled in nitric acid, a portion of oil soluble in alcohol was likewise formed †. Club moss.

* *Ann. de Chim.* lxii. 81.

† Gehlen's *Jour.* vi. 593.

[illegible] equally various with [illegible]
[illegible] hitherto subjec[illegible]
[illegible] all contain an ac[illegible]
[illegible] tartaric, the oxa[illegible]
[illegible] mixture of two or more
[illegible] perhaps the ace[illegible]
[illegible] They usually c[illegible]
[illegible] gummy matter, someti[illegible]
[illegible] contain likewise a fibr[illegible]
[illegible] examined. The colour[illegible]
[illegible] the red, dissolve rea[illegible]
[illegible] but very speedily de[illegible]
[illegible] of the sun and weat[illegible]
[illegible] as dyes.

[illegible] a considerable n[illegible]
[illegible] already in a former [illegible]
[illegible] As very few vegetable fruits have
[illegible] little can be added to what
[illegible] The only analyses, indeed, hitherto p[illegible]
[illegible] and grapes.

[illegible] —This substance consists chiefly c[illegible]
[illegible] the pods of the *tamari*[illegible]
[illegible] It is brought to Eu[illegible]
[illegible] We are indebted to Vauqu[illegible]

for an analysis of this substance, published however at a very early period of his chemical career. By treating the pulp of tamarinds, such as they are sold by the apothecaries, first with cold water, and afterwards with hot, he separated the following substances*: Chap. II.

Supertartrate of potash	300
Gum	432
Sugar	1152
Jelly	576
Citric acid	864
Tartaric acid	144
Malic acid	40
Feculent matter	2880
Water	3364
	9752

2. *Grapes.*—Though grapes have been repeatedly examined by chemists, we are not yet in possession of an accurate chemical analysis of their constituents. It has been ascertained, however, that they contain supertartrate of potash, tartaric acid, citric and malic acids†. They contain also abundance of sugar, a portion of mucilage and jelly, some albumen and colouring matter, and, according to Proust, a portion of gluten. Grapes.

Pears, apples, lemons, oranges, &c. have not yet been subjected to a chemical examination. The few facts which have been ascertained respecting them are detailed in a different part of this Work.

* *Ann. de Chim.* v. 92.

† Bouillon, *Jour. de Phys.* xxix. 3.—Parmentier, *Ann. de Chim.* liii. 119.

[illegible]

[illegible] connected with [illegible]
[illegible] to the *buds*, and c[illegible]
[illegible] plant. The *potatoe* i[illegible]
[illegible]
[illegible] their constituents a[illegible]
[illegible] parts of plants ; [illegible]
[illegible] considerable resembla[illegible]
[illegible] are cultivated un[illegible]
[illegible] constitutes a nota[illegible]
[illegible] hitherto examined. Hen[illegible]
[illegible] as articles of food. Fe[illegible]
[illegible] subjected to a chemical an[illegible]
[illegible] specify the following:
[illegible] of the [illegible]*num tuberosu*[illegible]
[illegible] to this country by S[illegible]
[illegible] cultivated in every part [illegible]
[illegible] constituting one of the most im[illegible]
[illegible] The plant and the bulb a[illegible]
[illegible] description.
[illegible] subjected to chemic[illegible]
[illegible] published an elaborate disse[illegible]
[illegible] properties, about th[illegible]
[illegible] considerably to promo[illegible]
[illegible] the continent. Dr Pears[illegible]

Chap. II.

contributed to the Board of Agriculture a valuable essay on potatoes, containing a set of chemical experiments on them, performed with his usual skill and ingenuity; and very lately Einhof has published a very elaborate analysis of the root in the fourth volume of Gehlen's Journal.

The variety of potatoe which chiefly occupied the attention of Einhof, was that which has a red skin and flesh-coloured juice. When dried by a moderate heat, till they ceased to lose any weight, potatoes were reduced to $\frac{1}{4}$th of their original weight*.

The analysis of this root was conducted by Einhof pretty much in the same manner as his analysis of barley and rye. A determinate quantity of potatoes was reduced with water to a pulp, and then washed on a searce till the liquid ceased to come off milky, or to hold any thing in solution. What remained on the cloth was the fibrous matter of the potatoe; but it differed essentially from the fibrous matter of most plants. With boiling water it formed a paste similar to that made by means of starch, and when dry it assumed a semitransparent appearance. This matter, when triturated in a mortar, and again washed with water, yielded a considerable portion of starch. The residue, which was of a light grey colour, being triturated a second time, formed a powder which bore a considerable resemblance to starch, both in its appearance and properties.

The liquid with which the potatoe was washed was at first milky, but deposited, on standing, a heavy

* Gehlen's *Jour.* iv. 457.

Book V.

[illegible] powder, which was *starch*. When filtered it had a carmine-red colour, and reddened vegetable blues. When boiled a flaky precipitate separated, partly white and partly red. This precipitate possessed the properties of albumen. The residue, evaporated to the consistence of an extract, had a brownish colour, was insoluble in alcohol and ether, soluble in water, and, according to Einhof, was a mucilaginous matter. The following were the proportions of these various substances obtained from 7680 parts of potatoes:

Composition.

Starch	1153
Fibrous starchy matter	540
Albumen	107
Mucilage, in the state of a thick syrup	312
	2112

[illegible] of the acid which exists in potatoes. [illegible] separated the juice of potatoes by a good press. He had first frozen and then thawed [illegible] to facilitate the separation. Lime-water was added in excess to this liquid, and the precipitate was [illegible] to separate the lime [illegible]. Thus obtained, it was found to be a [illegible] phosphoric acids *. The sap, [illegible] excess of lime [illegible]. Einhof found, that [illegible] with carbonic acid [illegible] was kept in close vessels;

* [illegible] method described [illegible] un- [illegible] and held [illegible]

and that in process of time, if a sufficient quantity of lime were present, the mucilage acquired a sweet taste; and when treated with alcohol, a portion dissolved, which yielded crystals of sugar. This he considered as a conversion of the mucilage into sugar. Chap. II.

Ashes. From 1820 parts of dried potatoes, Einhof obtained 96 parts of a greyish white ash. Of these, 64 parts were soluble in water. They consisted chiefly of carbonate of potash; but contained likewise $10\frac{1}{2}$ parts of phosphoric acid, $3\frac{1}{2}$ of sulphuric acid, and two of muriatic. The insoluble 35 parts consisted of earths and oxides. From 20 parts of it he obtained

2·5 silica
6·0 lime
4·0 alumina
7·0 magnesia, with some manganese or oxide of iron.

19·5

Einhof examined different kinds of potatoes. He found the same ingredients in all, but the proportions varied considerably. It is not necessary to state the results of his experiments, because the same variations doubtless occur even in the same kind of potatoe.

But as it may be useful to know the quantity of starch furnished by different varieties of potatoe, the following table, drawn up from the experiments of Mr William Skrimshire junior, is subjoined. Five pounds avoirdupois of fresh potatoes were used, and the starch was separated by grating the potatoe, and pouring water upon it placed upon a searce *.

* Nicholson's *Jour.* xxi. 71.

Book IV.

Substances.	Varieties of potatoes used.															
	Captain hart.		Rough red.		White kidney.		Moulton white.		Yorkshire kidney.		Hundred eyes.		Purple red.		Ox noble.	
	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.
Fine starch	0	9	0	7¼	0	0	0	9	0	8¾	0	8¼	0	8	0	6¾
Ditto slightly coloured	0	3	0	3½	0	9¼	0	0½	0	2¼	0	0¼	0	6½	0	1
Pulp dried	0	6	0	6¼	0	3½	0	5¼	0	6¼	0	6¼	0	5	0	[illegible]
Water, mucus, and extractive	3	14	3	15	4	3¼	3	14¼	3	14¼	4	0¼	4	2½	3	15¼
Total	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0

Action of frost on potatoes.

When potatoes are exposed to the action of frost, i is well known that they become soft, and acquire sweet taste. This taste is succeeded by a sour tas owing to the rapid evolution of acetic acid, and root soon passes to putrefaction. From the experime of Einhof, we learn that the sugar is formed at the pence of the mucilage; for the other ingredients w found, in potatoes sweetened by frost, in the usual p portions. He considers this sweetening process as c nected with the vegetative powers of the root.

When potatoes are boiled, they lose from one to $1\frac{2}{7}$ *per cent.* of their weight. The juice, which may be separated from them, is sweet-tasted. The meal is insoluble even in boiling water, though potatoe starch forms a transparent solution with hot water. Thus it appears, that by boiling, the albumen, fibrous matter, and starch combine together, and form an insoluble compound *.

Chap. II. Boiling.

From these experiments, it appears that potatoes differ essentially from wheat and barley by containing no gluten. They approach, in some measure, to the nature of rye.

2. *Garlic.*—This is the bulbous part of the root of the *allium sativum*, and is well known, and remarkable for its strong smell and peculiar taste. It was much celebrated by the ancients, both as an article of food and as a medicine. It has been repeatedly examined by chemists. The analysis of Neumann, considering the state of the art of examining vegetables at that time, must be considered as very exact †. Cadet has lately subjected it to a chemical examination ‡.

Garlic.

When dried, it loses nearly two-thirds of its weight; but this proportion is doubtless subject to considerable variation. The expressed juice of garlic is of a thick consistence like mucilage, and slightly reddens vegetable blues. When diluted with water, and filtered, it yields flakes of albumen when boiled. The residue consists chiefly of mucilage, of which garlic yields a very great proportion, and of extractive. This last is somewhat acrid in its nature. When garlic is distilled

* Gehlen's *Jour.* iv. 485.
† Neumann's *Chem.* p. 481.
‡ *Ann. de Chim.* lix. 106.

employed
oxide of
our ; b
liquid
When
33
58
2
15·6

Chap. II.

From 1406 parts of fresh garlic he obtained

Mucilage	520
Albumen	37
Fibrous matter	48
Water, by estimate...	801
	1406

Onion.

3. *Onion.* This is the bulbous root of the *allium cepa.* A few experiments on it had been made by Neumann and Cadet. But Fourcroy and Vauquelin have lately published a very curious and accurate analysis of it. When reduced to a pulp, and subjected to the press, it yields a viscid juice, somewhat opaque, at first colourless, but becoming gradually red in consequence of the oil which it contains. It has a strong smell, and reddens vegetable blues. It is precipitated by acetate of lead, lime water, oxalic acid, nitrate of silver, and potash. When distilled it yields a milky liquid, slightly acid, on the surface of which swim some drops of oil. It contains a little sulphur dissolved in the oil; for oxymuriatic acid gives it the property of precipitating nitrate of barytes, and when distilled in a copper vessel some sulphuret of copper is formed. The portion of juice not distilled deposites a fawn coloured sediment, having a strong oniony odour. Alcohol deprives this sediment of oil and of sulphur; the residue seems to possess properties analogous to those of gluten. The liquid, from which this precipitate has separated, contains phosphoric acid, sulphur, and gluten.

When onion juice is kept at a temperature between 60° and 70° it emits no gas, but it changes its colour successively to red and yellow, and lets fall a fawn coloured sediment. It is now converted into vinegar still

[illegible]

SECT. XI.

OF LICHENS.

History.

re lichens are a class of plants which differ almost
very respect from other vegetables. Many of them
e not the smallest appearance of plants, but form
l crusts, which cover rocks, wood, trees, &c.; others
e the form of leaves or of branches, but nothing re-
bling flowers is visible. It was to Tournefort and
heli that botany is indebted for first fixing the
d *lichen*, formerly vague and ill defined, to a pecu-
set of plants. Afterwards Linnæus placed them
ng the algæ, and described 81 species. Since that
a great variety of botanical writers have devoted
iderable attention to them, particularly in ascer-
ng and describing their parts of fructification, and
various changes which they undergo in the differ-
periods of their vegetation; but few only have at-
pted to analyse them, or to point out the useful pur-
s to which they may be applied. Willemet has
n us a historical account of 41 species of lichens,
detailed their medical and economical uses with
iderable accuracy. Amoreux, in a dissertation on
subject, has given us still more copious details,
has published likewise a brief chemical analysis of
of the most remarkable lichens. Hoffmann, who
previously distinguished himself by his botanical
ngement of the lichens, published an account of

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their chemical and economical properties in 1787, and has given us the chemical analysis of several, made by Georgi with considerable care. Westring turned his attention particularly to the uses of the lichens in dyeing; and in seven dissertations, published successively in the Stockholm Transactions from 1792 to 1797, has examined almost all the lichens of the north, and described the colours which each of them is capable of yielding, and the manner of obtaining it. It is to these writers and to Georgi, that we are indebted for the few facts known respecting the composition and chemical properties of the lichens.

The lichens are found in all countries and climates, and are very numerous; considerably more than two hundred species have been described by botanists as natives of Britain.

Some lichens contain gum.

From the experiments of Georgi, professor of chemistry in Petersburgh, we learn that the lichen farinaceus, glaucus, and physodes, form with water a mucilage which yields, when evaporated, a gum as transparent and tasteless as gum arabic. Lichen pulmonarius yields likewise a gum, but its taste is somewhat bitter. The gum yielded by these lichens amounted to $\frac{1}{7}$th of their weight. When treated with alcohol, the liquid acquires a green colour and a bitter taste *. Amoreux, who repeated these experiments, obtained from the lichen pulmonarius a reddish gum, much less transparent than gum arabic. This lichen gave a yellow colour to alcohol. Probably he had examined a different

* See the experiments of Georgi, as quoted by Amoreux, in his *Recherches et Expériences sur les divers Lichens*, p. 94.

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species from that tried by Georgi, or if not, the lichens must have been of very different ages.

Amoreux found, that when the lichen prunastri was steeped in water, its branches became transparent like animal membrane, and adhered strongly to paper. In this state it is insipid, but as friable as celery. He obtained abundance of gum from the lichen islandicus, and from all the broad-leaved lichens tried. He succeeded in extracting gum from the lichen fraxineus, caninus, and caperatus. This last gave a lemon yellow colour to ammonia *.

Some may be used as food.

Georgi found, that when the lichen physodes, hirtus, farinaceus, and pulmonarius, were boiled in water, they yielded a yellowish mucilage nearly insipid, and that the lichens thus treated might be eaten with salt. They all yielded a portion of resin to alcohol, but it did not taste the water in which they were boiled. When incinerated, these lichens yielded a little potash, lime, and silica, but no sulphuric or muriatic salt. When distilled, they yielded an acidulous water, and a yellow or blackish oil which sunk in water.

Such are the imperfect experiments hitherto made on the constituents of a few of the lichens. I shall now mention such of them as are most remarkable for the colouring matters which they yield.

Archil.

1. *Lichen roccella.*—This lichen which grows abundantly in the Canary islands, but which is found also on the south coast of England and France, yields the dye stuff called *archil.* If we belief Tournefort, this dye stuff was known to the ancients, and was employed to

* See the experiments of Georgi, as quoted by Amoreux in his *Researches et Experiences sur les divers Lichens*, p. 95.

Other lichens yielding colouring matters.

3. *Lichen pertusus.*—Treated with lime and sal-ammoniac, it yielded a brown colouring matter to Westring.

4. *Lichen ventosus.*—This lichen dyed wool of a brown colour, which resisted the action of alkalies.

5. *Lichen hæmatoma* yielded a wax yellow colour.

6. *Lichen corralinus.*—This lichen was found by Westring to abound in colouring matter. By simple infusion in water with a little common salt, it dyed wool yellow. Without addition, it gives a deep brown of considerable permanence. It yielded the same colour when treated with sal-ammoniac and lime.

7. *Lichen pseudo-corralinus* yielded a fine orange, which was brightened by muriate of cobalt.

8. *Lichen tartareus* yielded a fine brown.

9. *Lichen centrifugus*, with fixed alkalies, yielded a fine wax yellow; with water, a brown; with common salt and nitre, an orange.

10. *Lichen saxatilis.*—This lichen, with soda, yields a yellow; with lime and sal-ammoniac, a nankeen; and with muriate of soda and nitre, an orange.

11. *Lichen physodes*, by the same reagents, yields various shades of yellow and brown; *lichen juniperinus*, yellow and brown; *lichen tenellus*, yellow, olive, and reddish brown; *lichen furfuraceus*, yellow and brown. The same colours were obtained from a considerable number of leafy lichens.

Lichen croceus, with lime and sal-ammoniac, gave out a red colour. Westring obtained several colours from other lichens; and by mixing several of them together, he varied the shade, and produced a new set of colours, differing both in their intensity and fixity. But for the particulars of his numerous experiments,

Book IV. the reader is referred to his dissertations on the subject *.

SECT. XII.

OF MUSHROOMS.

The mushrooms are a class of plants proverbial for the rapidity of their growth and their speedy decay. When they putrefy, they give out an extremely unpleasant odour, and appear to approach animal matter much more closely than other vegetable substances. A chemical analysis of the more remarkable species would be curious, and would probably make us acquainted with several new substances; but hitherto, as far as I know, the following species only have been chemically examined.

Boletus laricis.

1. *Boletus laricis.*—This plant, in a dry state, is used on the continent as a medicine, and sold under the name of *agaric*. It has been lately examined by Bouillon la Grange †.

It is in pieces, which are white, light, and friable. The outer skin is leathery and dark-coloured. Its taste is at first sweetish, but it leaves a bitter and acrid

* The first has been translated into French, and printed in vols. xv. and xvii. of the *Annales de Chimie*. The others are inserted in Crell's *Annals* for 1796, 1797, and 1799.

† *Ann. de Chim.* li. 76.

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sion in the mouth. When steeped in water, it unicates a yellowish colour and a sweetish taste liquid. The infusion reddens vegetable blues; olds in solution sulphate of potash, sulphate of and muriate of potash.

ien this substance is boiled in water, the liquid es a gelatinous form as it cools. Evaporated to ss, and treated with lime, the odour of ammonia nes perceptible. Alcohol, boiled upon the boletus, res a red colour; and when mixed with water, ll a copious precipitate, which exhibits the pro- s of a resin. This resin has a yellow colour, is , semitransparent, and has a sour and bitter taste. treated with lime, and the solution afterwards posed with muriatic acid, a quantity of benzoic obtained from it. From these experiments, it lent that this substance contains resin, benzoic different salts, some extractive, and some animal r, to which the gelatinous form of the decoc- nust be ascribed.

phuric acid dissolves and rapidly chars the boletus. acid acts with energy; nitrous gas is disengaged, e boletus becomes brown. By continuing the of the acid, crystals of oxalic acid are obtained; acid is likewise formed, together with some re- d a substance which approaches the nature of its properties. The fixed alkalies give it a red , render it gelatinous, and a great quantity of am- is disengaged *.

Boletus igniarius.

Boletus igniarius.—This boletus is not uncom-

* Bouillon la Grange, *Ann. de Chim.* li. 76.

[illegible] [illegible] of trees. A variety [illegible] [illegible] some other countries as [illegible] [illegible] purpose by boiling it in [illegible] [illegible] [illegible] till it becomes soft [illegible] [illegible] boiling it a second time in the same [illegible] [illegible] was recommended by Bros[illegible] [illegible] [illegible] excellent styptic; and va[illegible] [illegible] [illegible] in France and Bri[illegible] [illegible] [illegible] to a chemical exa[illegible] [illegible] [illegible].*

[illegible] [illegible] acquires a deep [illegible] [illegible] [illegible]. It holds [illegible] [illegible] of lime and [illegible] of potash. [illegible] [illegible] leaves a [illegible]-colour[illegible] [illegible] which attracts moisture from the atmosphere. [illegible] [illegible] and a white [illegible] [illegible] considerable portion of [illegible]; and [illegible] [illegible] water, exhibited, by [illegible], the presence of lime, and of muriatic and [illegible] acids. The [illegible] portion of the boletus, being [illegible], was found to contain phosphates of lime and magnesia, and some iron.

Alcohol has scarcely any action on this [illegible]; but when assisted by heat, it dissolves a small portion of resin. Nitric acid dissolves it readily; malic and oxalic acids are formed, and probably also a portion of bitter principle, while carbonic acid and nitrous gas are disengaged. Alkaline leys dissolve it with difficulty; forming, however, a soapy liquid, and separating a small portion of ammonia. From these experi-

* *Ann. de Chim.* liv. 92.

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ments, we learn that this boletus differs in many respects from the preceding. It contains much less resin, and a much smaller proportion of animal matter, and yields no traces of benzoic acid *.

Truffles.

3. *Lycoperdon tuber*, or *tuber cibarium; truffles*.—This is a globular fungus found four or five inches under ground, in woody places, and is considered as one of the best of the eatable mushrooms. Bouillon la Grange has lately subjected it to a chemical analysis †. It was attempted nearly in the manner formerly described for ascertaining the constituents of the different species of corn.

It was grated down small, and then washed with water upon a searce, till the liquid ceased to carry off any thing. A blackish fibrous matter remained upon the searce. The liquid let fall a brown coloured matter when left at rest. The liquid produced no effect upon vegetable blues. The brown deposite does not resemble starch in its properties. Water produces but little effect upon truffles. Warm water, however, dissolves a portion, which possesses the characters of albumen.

When the plant was treated with nitric acid, a solution was accomplished; nitrous gas, carbonic acid, and azotic gas were disengaged; and the solution, by distillation, yielded a liquor containing prussic acid. The residual liquid yielded bitter principle, an oily matter, and small crystals, which Bouillon la Grange considered as a combination of oxalic acid and bitter principle. He suspected also the presence of malic acid.

* Bouillon la Grange, *Ann. de Chim.* liv. 92.
† *Ann. de Chim.* xlvi. 197.

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Alcohol dissolves a small portion of brownish bitter matter, which acquires the properties of resin by exposure to the atmosphere.

When truffles are left in the state of a paste with water, they acquire the smell of cheese. When mixed with sugar and water they undergo fermentation, carbonic acid is disengaged, and alcohol formed.

When distilled, truffles yield an acid liquid, a black oil, carbonate of ammonia, carbonic acid, and carburetted hydrogen. The charcoal contains magnesia, phosphate of lime, iron, and silica *.

Several experiments have been likewise made upon this plant by Robert and Antoine, which confirm those of Bouillon la Grange.

Agaricus piperatus.

4. *Agaricus piperatus*.—From the observations of Trommsdorf, we learn that this plant contains a great portion of a peculiar acrid matter, and abundance of albumen. When distilled it yields a considerable quantity of carbonate of ammonia †. This mushroom was examined by Dr Lister, and the result published in the Philosophical Transactions for 1672 ‡. He found them to yield a milky juice with a taste hotter than pepper, not discoloured by exposure to the air, nor by the blade of a knife. This juice speedily coagulated when kept in a glass vessel, but did not lose its hot taste.

Though this is the only species of the numerous family of agarics hitherto subjected to chemical analysis, many others are highly deserving of attention. The *agaricus campestris*, *coriacius*, *deliciosus*, and a few

* Bouillon la Grange, *Ann. de Chim.* xlvi. 197.
† *Ann. de Chim.* xxii. 220. ‡ Vol. vii. p. 5116.

thers, are very commonly served up as an article of food, and form the basis of various sauces. Other species of *agaricus*, as the *muscarius*, *piperatus*, &c. possess very deleterious qualities. Chap. II.

The same remarks apply to the different species of *boleti*. Much curious information might be expected from the analyses of the *phallus esculentus* and the *phallus impudicus*, so remarkable for the abominable odour which it diffuses all around, and for the suddenness with which it runs to putrefaction.

SECT. XIII.

OF THE DISEASES OF PLANTS.

Having now given such an account of the parts of plants as the present imperfect state of vegetable chemistry permitted, it remains for us to point out the new substances generated in plants by disease, and to describe the properties of these substances. But though the diseases of plants are numerous and well marked, and though the effects which they produce on those vegetables which are employed as articles of food are often severely felt, yet little progress has been made, either in ascertaining the nature of these diseases, or the method of preventing or removing them. The following are the only observations, strictly chemical, which can be at present offered:

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Ulcers.

1. Old trees are frequently affected with a kind of ulcer, the chief seat of which is under the bark. There the juices undergo a change, and acquire a certain acridity, which enables them to corrode and destroy the solid parts of the plant. We are indebted to Vauquelin for an examination of the sanies or morbid liquid which flows from the ulcer in these cases. He collected the matter which he examined from the elm, which is particularly subject to this disease *.

This liquor is sometimes nearly transparent like water, and having an acrid and saline taste; sometimes it is slightly coloured, sometimes blackish or brown. It deposites upon the sides of the ulcer a soft matter, which is insoluble in water. The bark over which the transparent sanies passes becomes white like chalk, acquires an alkaline taste, and effervesces powerfully with acids. It becomes friable, loses its fibrous texture, and exhibits the appearance of crystals. By means of a glass small rhomboids and four-sided prisms can be distinguished in it. When the liquid is dark coloured, the bark assumes a black appearance, and looks as if covered with a coat of varnish. This black matter is sometimes in such quantity that it assumes the appearance of stalactites. It is soluble in water, has an alkaline taste, and effervesces with acids.

The white matter which was deposited on the bark of the elm round the ulcer, was found composed of

* *Ann. de Chim.* xxi. 39.

60·5 vegetable matter
34·2 carbonate of potash
5·0 carbonate of lime
0·3 carbonate of magnesia

100·0

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lack shining matter consisted of carbonate of nd a peculiar substance which possessed most operties of *gum*, though it differed from that in several particulars.

estructive tendency of such ulcers in trees is ly obvious. Vauquelin has shown, that to the quantity of white matter which surrounded of the elm, and on which he made his expe- 500 lbs weight of the wood of the tree must n destroyed *.

Blight in wheat.

e blight is a disease which attacks the different f corn, especially wheat, and in some seasons estroys the crop. It begins first upon the d stem, and at last, attacking the seed, destroys rable part, or even the whole of it, leaving a tter in its place. Botanists have shown, that matter is a species of small fungus, which nourishment from the wheat †. The wheat ed with the black fungus has been lately exa- Fourcroy and Vauquelin, in order to ascer- far the experiments of former chemists were The result of their examination has been pub-

e Chim. xxi. 39.

account of this fungus, with figures of it, and ingenious especting its propagation, by Sir Joseph Banks. Nicholson's

... volume of the *Annales de Museum* ... *naturelle* *.

... the wheat was macerated with alcohol, it gave ... of acrid oil, of the consistence of butter, ... green colour. Water in which it was steeped acquired acidity, and when saturated with potash let fall an animal matter, mixed with phosphate of ammonia-and-magnesia, and held phosphate of potash in solution. Of course, the acid which it contained was the phosphoric. It still retained in solution a matter similar to gluten of wheat allowed to run into putrefaction. The residue, distilled, yielded water, holding in solution acetic acid and acetate of ammonia, a brown oil, and a quantity of charcoal, amounting to nearly $\frac{1}{7}$th of the original weight. The result of the experiments was, that blighted wheat contained an acrid oil, putrid gluten, charcoal, phosphoric acid, phosphate of magnesia and ammonia, and phosphate of lime; but no traces of starch could be detected.

3. Barley is subject to a similar disease with wheat, and, doubtless, from the same cause. Einhof has lately subjected this grain, damaged by the *rubigo*, or blight, to a chemical examination. The result of his trials coincides pretty nearly with the experiments of Fourcroy and Vauquelin on blighted wheat. He could detect no starch in it. The infusion of it in water reddened vegetable blues, and contained an acid, which appeared to be the phosphoric. There was present a peculiar animal matter, differing in its properties from any of the principles of barley, and a quantity of charcoal †.

* No. xxxv. p. 332.

† Gehlen's *Jour*. vi. 91.

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CHAP. III.

OF VEGETATION.

have now seen the different substances which are ied in plants, and of which they are composed: have still to examine the manner in which these ices are produced, and to endeavour to trace the it processes which constitute vegetation. But I varn the reader not to expect complete informa- this Chapter. The wonders of the vegetable m are still but very imperfectly explored; ma- the organs of plants are too minute for our sen- id scarcely a single process can be completely

multiplicity of operations continually going on tables at the same time, and the variety of dif- and even opposite substances, formed out of the ngredients, and almost at the same place, astonish nfound us. The order, too, and the skill with every thing is conducted, are no less surprising. o operations clash; there is no discord, no irregu- no disturbance; every object is gained, and eve- g is ready for its intended purpose. This is too rful to escape our observation, and of too much ance not to claim our attention. Many philoso-

Book IV. phers, accordingly, distinguished equally by their industry and sagacity, have dedicated a great part of their lives to the study of *vegetation*. But hitherto their success has not been equal to their exertions. No person has been able to detect this *Agent*, always so busy, and performing such wonders, or to discover him at his work; nor have philosophers been much more fortunate in their attempts to ascertain the instruments which he employs in his operations. A great variety, however, of curious and interesting facts have been discovered. These I shall attempt in the following Sections to collect and arrange, to point out their dependence on each other, and perhaps to deduce such consequences as obviously result from this mutual dependence.

SECT. I.

OF GERMINATION.

Plants produced from seeds.

1. NATURAL historians have proved, by a very complete induction of facts, that all plants arise from *seeds*. The pretended exceptions have disappeared, one after another, as our knowledge of vegetables increased: and now there remains scarcely a single objection entitled to the smallest regard. The late attempt of Girtanner* to revive the doctrine of equivocal generation, deserves no attention whatever; because his conclusions are ab-

* *Ann. de Chim.* xxxiv. 35.

utely incompatible with the *experiments* of Mr Senne- Chap. III
er upon the very substance on which his theory is
unded.

A SEED consists of three parts: namely, the *cotyle-* Seeds composed of three parts;
es, the *radicle*, and the *plumula*, which are usually in-
osed in a cover.

If we take a garden bean, we may perceive each of viz. Cotyledon,
ese three parts with great ease; for this seed is of so
rge a size, that all its organs are exceedingly distinct.
hen we strip off the external coats of the bean, which
e two, and of different degrees of thickness in differ-
t parts, we find that it easily divides into two lobes,
etty nearly of the same size and figure. Each of
ese lobes is called a *cotyledon* (fig. 40. *a*). The coty-
lons of the bean, then, are two in number.

Near that part of the lobes which is contiguous to Radicle,
at is called the *eye* of the bean, there is a small round
ite body (*b*), which comes out between the two
s. This body is called the *radicle*.

ttached to the radicle there is another small round Plumula.
(*c*), which lies between the cotyledons, and whol-
ithin them, so that it cannot be seen till they are
ated from each other. This body is called the
la.

e appearance and shape of these three parts differ
uch in different seeds, but there is no seed which
them. The figure and size of the seed depend
upon the cotyledons. This is evidently the case
e bean, and it is so with all other seeds. The
of cotyledons is different in different seeds.
eds have only one cotyledon, as the seeds of
ats, barley, and the whole tribe of grasses;
e three; others six, as the seeds of the garden

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cress; but most seeds, like the bean, have two cotyledons.

Germination

2. When a seed is placed in a situation favourable to vegetation, it very soon changes its appearance. The radicle is converted into a root, and sinks into the earth, the plumula on the other hand, rises above the earth, and becomes the trunk or stem. When these changes take place, the seed is said to *germinate*: the process itself has been called *germination*. Seeds do not germinate equally and indifferently in all places and seasons. Germination, therefore, is a process which does not depend upon the seed alone: something external must also affect it.

Requires moisture,

3. It is a well known fact, that seeds will not germinate unless *moisture* have access to them; for seeds, if they are kept perfectly dry, never vegetate at all, and yet their power of vegetating is not destroyed. *Water*, then, is essential to germination. Too much water, however, is no less prejudicial to most seeds than none at all. The seeds of water plants, indeed, germinate and vegetate extremely well in water; but most other seeds, if they are kept in water beyond a certain time, are rotted and destroyed altogether.

Heat,

4. It is well known also, that seeds will not germinate, even though supplied with water, provided the temperature be below a certain degree. No seed, for instance, on which the experiment has been tried, can be made to vegetate at or below the freezing point: yet this degree of cold does not injure the vegetating power of seeds; for many seeds will vegetate as well as ever after having been frozen, or after having been kept in frozen water. We may conclude, then, that a certain degree of heat is necessary for the germination of seeds:

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every species of plant seems to have a degree pe-
r to itself, at which its seeds begins to germinate ;
very seed has a peculiar season at which it begins
rminate, and this season varies with the tempera-
of the air. Mr Adanson found that seeds, when
at the same time in France and in Senegal, always
ared sooner above ground in the latter country,
e the climate is hotter than in France *.

And oxygen gas.

Seeds, although supplied with moisture and pla-
in a proper temperature, will not germinate, pro-
l atmospherical air be completely excluded from
. Mr Ray found that grains of lettuce did not
inate in the vacuum of an air pump, but they be-
to grow as soon as air was admitted to them †.
berg made a number of experiments on the same
ct, which were published in the Memoirs of the
h Academy for the year 1693. He found, that
reater number of seeds which he tried refused to
ate in the vacuum of an air-pump. Some, how-
did germinate: but Boyle, Muschenbroek, and
haave, who made experiments on the same subject
ccession, proved beyond a doubt that no plant ve-
es in the vacuum of an air-pump; and that in
cases in which Homberg's seeds germinated, the
um was far from perfect, a quantity of air still re-
ing in the receiver. It follows, therefore, that no
will germinate unless atmospherical air, or some
aving the same properties, have access to it. It is
his reason that seeds will not germinate at a certain
h below the surface of the earth.

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* *Encyc. Method. Physiol. Veget.* 124. † *Phil. Trans.* No. liii.

Mr Scheele found that beans would not g[illegible] except oxygen gas were present. Mr Achard al[illegible] proved, that oxygen gas is absolutely necessar[illegible] germination of all seeds, and that no seed wil[illegible] [illegible] gas, [illegible] mixture of oxy[illegible] [illegible] been confirmed by M[illegible] [illegible] many other philosophe[illegible] [illegible] not the whole an[illegible] [illegible] oxygen gas which it cont[illegible] [illegible] the germination of seeds.

[illegible] has ascertained, that [illegible] [illegible] when steeped in oxy-muriati[illegible] [illegible] with it; and this acid is well k[illegible] [illegible] which it parts with its oxyg[illegible] [illegible] to augment the vegetative [illegible] [illegible] several seeds which had [illegible] [illegible] which had constantly refused to g[illegible] [illegible] were treated with this acid ‡.

[illegible] has considerable influence on [illegible] [illegible] seeds. Ingenhousz found that see[illegible] [illegible] faster in the dark than when expo[illegible] [illegible]. His experiments were repeated by M[illegible] [illegible] equal success §. But the Abbé [illegible] [illegible] distinguished himself so much by his [illegible] [illegible] on the effect of electricity on vegeta[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

jected to the conclusions of these philosophers, and affirmed that the difference in the germination of seeds in the shade and in the light was owing, not to the light itself, but to the difference in the moisture in the two situations; the moisture evaporating much faster from the seeds in the light than from those in the shade; and he affirmed, that when precautions were taken to keep the seeds equally moist, those in the sun germinated sooner than those in the shade *. But when Mr Sennebier repeated his former experiments, and employed every possible precaution to ensure the equality of moisture in both situations, he constantly found the seeds in the shade germinate sooner than those in the light †. We may conclude, therefore, that light is injurious to germination; and hence one reason for covering seeds with the soil in which they are to grow. But from the recent experiments of Saussure, there is reason to believe that light is only injurious in consequence of the heat which it produces; for when the direct rays of the sun were intercepted, though light was admitted, the germination of the seeds was not sensibly retarded ‡.

7. Thus we have seen that seeds will not germinate unless *moisture*, *heat*, and *oxygen* be present. Now, in what manner do these substances affect the seed? What are the changes which they produce?

Phenomena of germination.

It was observed before, that all seeds have one or more cotyledons. These cotyledons contain a quantity of farinaceous matter, laid up on purpose to supply the

* *Jour. de Phys.* 1789, December.

† *Encyc. Meth. Physiol. Veget.* 126.

‡ *Recherches Chimiques sur la Vegetation*, p. 23.

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embryo plant with food as soon as it begins to require it. This food, however, must undergo some previous preparation, before it can be applied by the plant to the formation or completion of its organs. It is probable that all the phenomena of germination, which we can perceive, consist in the chemical changes which are produced in that food, and the consequent developement of the organs of the plant.

Carbonic acid emitted.

When a seed is placed in favourable circumstances, it gradually imbibes moisture, and very soon after emits a quantity of carbonic acid gas, even though no oxygen gas be present *. If no oxygen gas be present, the process stops here, and no germination takes place; but if oxygen gas be present, a portion of it is converted into carbonic acid gas. From the experiments of Saussure, it appears, that if seeds be left to germinate in a determinate portion of oxygen gas or common air, the bulk of that gas is not altered; the carbonic acid formed being equal to the oxygen which has disappeared. Hence it follows, that the carbonic acid contains in it exactly the whole oxygen consumed †. No oxygen, then, is absorbed by the seed; or at least, if it be absorbed, none of it is retained, the whole being thrown out in combination with carbon. The quantity of oxygen thus changed into carbonic acid by the germination of seeds, is in some measure proportional to the weight of the seed; but some seeds require more than others. In the experiments of Saussure, wheat and barley, weight for weight, consumed less oxygen than peas; while peas consumed less than beans and kidney-beans. The

Oxygen of the air diminished.

* Gough, *Manch. Mem.* iv. 315.—Cruikshank, Rollo on *Diabetes*, p. 452.

† *Jour. de Phys.* xlix. 92.

oxygen consumed by wheat and barley amounts to between $\frac{1}{1000}$th and $\frac{1}{2000}$th of their weight; while that consumed by beans and kidney-beans may amount to $\frac{1}{100}$th part of their weight *. Similar experiments were made by Dr Woodhouse †. Chap. III.

It does not appear that any water is decomposed during the process of germination, at least we have no evidence that it is so. Neither hydrogen nor oxygen gas are emitted. It would not be surprising if a portion of water, so far from being decomposed, were actually formed by the union of its constituents previously existing in the grain. When Saussure dried seeds at a certain temperature before germination, and afterwards brought them to the same degree of dryness after germination, he always found that the loss of weight was greater than it ought to have been. Thus 73 peas, which together (when dried at 77°) weighed 200 grains, when left with five times their weight of water in a vessel full of air, and standing over mercury for two days, germinated, and produced $4\frac{4}{5}$ cubic inches of carbonic acid. They were taken out, and dried slowly at the same temperature; during their drying they changed $4\frac{1}{2}$ cubic inches more of oxygen into carbonic acid. Now these nine inches of carbonic acid contain 1·7 grains of carbon. The water in which peas had been placed while germinating, when evaporated to dryness, left 0·75 grains of mucilaginous matter. Thus the peas, by germinating and drying, ought to

* *Recherches*, p. 13.

† He tried the seeds of the zea mays, opium petroselinum, lactuca sativa, cucurbita citrulla, phaseolus sativus, sisymbrium sativum, raphanus sativa. They changed oxygen into carbonic acid. Nicholson's *Jour.* ii. 161.

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have lost only 2·45 grains, leaving a residue of 197·55 grains. But their weight was only 189 grains. So that they had lost eight grains more than can be accounted for by the mucilage taken up by the water and carbonic acid formed. We are obliged to suppose this loss owing to water. From Saussure's experiments, this water seems to be formed or set at liberty during the drying of the seeds, for the quantity of it always increased with the slowness of the process of drying *.

Food prepared in the cotyledons.

Several seeds, by germinating, acquire a sweetish taste. Hence it has been supposed, that the mucilage which they contain is converted into saccharine matter. We see that the carbon is diminished by germination; and unless water be formed, the proportion of hydrogen and oxygen must be proportionably augmented. It is obvious from the process of malting, that heat is generated during germination. I have seen the radicles of barley, when kept without turning on the malt-floor, shoot out half an inch in a single night, and the heat rise as high as 100°.

So far seems to be the work of chemistry alone; at least we have no right to conclude that any other agent interferes; since *hay*, when it happens to imbibe moisture, exhibits nearly the same processes. Carbonic acid gas is evolved, oxygen gas is absorbed, heat is produced so abundantly, that the hay often takes fire: at the same time a quantity of sugar is formed. It is owing to a partial change of the same kind that old hay generally tastes much sweeter than new hay. Now we have no reason to suppose that any agents peculiar to the

* Saussure, *Recherches Chimiques sur la Vegetation*, p. 17.

vegetable kingdom reside in hay; as all vegetation, and all power of vegetating, are evidently destroyed. Chap. III.

But when the farina in the seeds of vegetables is converted into sugar, a number of vessels make their appearance in the cotyledon. The reader will have a pretty distinct notion of their distribution by inspecting fig. 41. These vessels may indeed be detected in many seeds before germination commences, but they become much more distinct after it has made some progress. Branches from them have been demonstrated by Grew, Malpighi, and Hedwig, passing into the radicle, and distributed through every part of it. These evi-
lently carry the nourishment prepared in the cotyle-
lons to the radicle; for if the cotyledons be cut off,
ven after the processes above described are completed,
ermination, as Bonnet and Sennebier ascertained by
periment, immediately stops. The food therefore is
nveyed from the cotyledons into the radicle; the ra-
le increases in size, assumes the form of a *root*, sinks
vn into the earth, and soon becomes capable of ex-
ting the nourishment necessary for the future growth
he plant. Even at this period, after the radicle has
me a perfect root, the plant, as Sennebier ascer-
d by experiment, ceases to vegetate if the *cotyledons*
it off. They are still, then, absolutely necessary
e vegetation of the plant.

And sent into the radicle,

Which becomes a root.

e cotyledons now assume the appearance of leaves,
ppear above the ground, forming what are called
inal leaves of the plant. After this the *plumula*
lly increases in size, rises out of the earth, and
s itself into branches and leaves. The seminal
soon after this, decay and drop off, and the plant

Seminal leaves

carries on all the processes of vegetation without their assistance.

As it does not appear that there is any communication between the cotyledons and the plumula, it must follow that the nourishment passes into the plumula from the radicle; and accordingly we see that the plumula does not begin to vegetate till the radicle has made some progress. Since the plant ceases to vegetate, even after the radicle has been converted into a root, if the cotyledons be removed before the plumula is developed, it follows that the radicle is insufficient of itself to carry on the processes of vegetation, and that the cotyledons still continue to perform a part. Now we have seen already what that part is; they prepare *food* for the nourishment of the plant. The root, then, is of itself insufficient for this purpose. When the cotyledons assume the form of seminal leaves, it is evident that the nourishment which was originally laid up in them for the support of the embryo plant is exhausted, yet they still continue as necessary as ever. They must therefore receive the nourishment which is imbibed by the root; they must produce some changes on it, render it suitable for the purposes of vegetation, and then send it back again to be transmitted to the plumula.

Digest the food sent by the root.

After the plumula has acquired a certain size, which must be at least a *line*, if the cotyledons be cut off, the plant, as Mr Bonnet ascertained by a number of experiments afterwards repeated with equal success by Mr Sennebier, does not cease to vegetate, but it continues always a mere pigmy: its size, when compared with that of a plant whose cotyledons are allowed to remain being only as two to seven *.

* *Encyc. Method. Physiol. Veget.* 42.

When the plumula has expanded completely into leaves, the cotyledons may be removed without injuring the plant, and they very soon decay of themselves. It appears, then, that this new office of the cotyledons is afterwards performed by that part of the plant which is above ground.

Thus we have traced the phenomena of germination as far as they have been detected. The facts are obvious; but the *manner* in which they are produced is a profound secret. We can neither explain how the food enters into the vessels, how it is conveyed to the different parts of the plant, how it is deposited in every organ, nor how it is employed to increase the size of the old parts, or to form new parts. These phenomena are analogous to nothing in mechanics or chemistry, but resemble exactly the organization and nourishment of animals. They belong therefore to that difficult branch of science known by the name of Physiology.

SECT. II.

OF THE FOOD OF PLANTS.

Plants, after they have germinated, do not remain stationary, but are continually increasing in size. A tree, for instance, every season adds considerably to its former bulk. The root sends forth new shoots, and the old ones become larger and thicker. The same increment takes place in the branches and the trunk. When

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we examine this increase more minutely, we find that a new layer of wood, or rather of alburnum *, has been added to the tree in every part, and this addition has been made just under the bark. We find, too, that a layer of alburnum has assumed the appearance of perfect wood. Besides this addition of vegetable fibre, a great number of leaves have been produced, and the tree puts forth flowers, and forms seeds.

Plants require food.

It is evident from all this, that a great deal of new matter is continually making its appearance in plants. Hence, since it would be absurd to suppose that they *create* new matter, it must follow that they receive it by some channel or other. Plants, then, require food as well as animals. Now, what is this food, and whence do they derive it? These questions can only be answered by an attentive survey of the substances which are contained in vegetables, and an examination of those substances which are necessary for their vegetation. If we could succeed completely, it would throw a great deal of light upon the nature of soils and of manures, and on some of the most important questions in agriculture. But we are far indeed at present from being able to examine the subject to the bottom.

Water necessary.

1. In the first place, it is certain that plants will not vegetate without water; for whenever they are deprived of it, they wither and die. Hence the well-known use

* The *wood*, when we inspect it with attention, is not, through its whole extent, the same; the part of it next the bark is much softer and whiter, and more juicy than the rest, and has for that reason obtained a particular name; it has been called the *alburnum* or *aubier*. The *perfect wood* is browner, and harder, and denser than the alburnum, and the layers increase in density the nearer they are to the centre.

of rains and dews, and the artificial watering of ground. Water, then, is at least an essential part of the food of plants. But many plants grow in pure water; and therefore it may be questioned whether water is not the only food of plants. This opinion was adopted very long ago, and numerous experiments have been made in order to demonstrate it. Indeed it was the general opinion of the 17th century; and some of the most successful improvers of the physiology of plants, in the 18th century, have embraced it. The most zealous advocates for it were, Van Helmont, Boyle, Bonnet, Duhamel, and Tillet.

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Supposed the sole food of plants;

Van Helmont planted a willow, which weighed five pounds, in an earthen vessel filled with 200 lbs of soil previously dried in an oven, and moistened with rain water. This vessel he sunk into the earth, and he watered his willow, sometimes with rain, and sometimes with distilled water. After five years it weighed $169\frac{1}{4}$ lbs, and the earth in which it was planted, when again dried, was found to have lost only two ounces of its original weight *. Here, it has been said, was an increase of 164 lbs. and yet the only food of the willow was pure water; therefore it follows that pure water is sufficient to afford nourishment to plants. The insufficiency of this experiment to decide the question was first pointed out by Bergman in 1773 †. He showed, from the experiments of Margraf, that the rain water employed by Van Helmont contained in it as much earth as could exist in the willow at the end of five years. For, according to the experiments of Margraf, one

* *Opera* Van Helmont, p. 105. *Complexionum atque Mistionum Elementalium Figmentum*, sect. 30. † *Opusc.* v. 92.

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pound of rain water contains one grain of earth *. The growth of the willow, therefore, by no means proves that the earth which plants contain has been formed out of water. Besides, as Mr Kirwan has remarked †, the earthen vessel must have often absorbed moisture from the surrounding earth, impregnated with whatever substance the earth contained; for unglazed earthen vessels, as Hales ‡ and Tillet § have shown, readily transmit moisture. Hence it is evident, that no conclusion whatever can be drawn from this experiment; for all the substances which the willow contained, except water, may have been derived from the rain water, the earth in the pot, and the moisture imbibed from the surrounding soil.

But without reason.

The experiments of Duhamel and Tillet are equally inconclusive; so that it is impossible from them to decide the question, Whether water be the sole nourishment of plants or not? But all the attempts hitherto made to raise plants from pure water have failed; the plants vegetating only for a certain time, and never perfecting their seeds. These experiments were made by Hassenfratz, Saussure, and others, with the same unfavourable result. Duhamel found, that an oak which he had raised by water from an acorn made less and less progress every year. We see, too, that those bulbous roots, such as hyacinths, tulips, &c. which are made to grow in water, unless they be planted in the earth every other year, refuse at last to flower, and even to vegetate; especially if they produce new bulbous roots annually, and the old ones decay. From all

* *Opusc.* ii. 15. and 19.
† *Irish Trans.* v. 160.
‡ *Veget. Stat.*
§ *Mem. Par.* 1772, 29

these facts and experiments, it is reasonable to conclude that water is not the sole food of plants *.

So far, indeed, is water from being the sole food of plants, that in general only a certain proportion of it is serviceable, too much being equally prejudicial to them as too little. Some plants, it is true, grow constantly in water, and will not vegetate in any other situation; but the rest are entirely destroyed when kept immersed in that fluid beyond a certain time. Most plants require a certain degree of moisture in order to vegetate well. This is one reason why different soils are required for different plants. Rice, for instance, requires a very wet soil: Were we to sow it in the ground on which wheat grows luxuriously, it would not succeed; and wheat, on the contrary, would rot in the rice ground.

We should, therefore, in choosing a soil proper for he plants which we mean to raise, consider the quanity of moisture which is best adapted for them, and hoose our soil accordingly. Now the dryness or moisre of a soil depends upon two things; the nature and oportions of the earths which compose it, and the antity of rain which falls upon it. Every soil cons at least three earths, silica, lime, and alumina, and netimes also magnesia. The silica is always in the e of sand. Now soils retain moisture longer or

he late experiments of Braconnot, who has endeavoured to prove ter is the sole food of plants, are by no means decisive. See *Ann.* lxi. 187. He raised plants on sand and metallic oxides by means , and found that the plants had all the usual vegetable, earthy, ine constituents. But in experiments of that nature it is imposuard against every channel, by means of which these substances access to plants.

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shorter according to the proportions of these earths. Those which contain the greatest quantity of sand retain it the shortest, and those which contain the greatest quantity of alumina retain it longest. The first is a dry, the second a wet soil. Lime and magnesia are intermediate between these two extremes: they render a sandy soil more retentive of moisture, and diminish the wetness of a clayey soil. It is evident, therefore, that by mixing together proper proportions of these four earths, we may form a soil of any degree of dryness and moisture that we please.

But whatever be the nature of the soil, its moisture must depend in general upon the quantity of rain which falls. If no rain at all fall, a soil, however retentive of moisture it be, must remain dry; and if rain were very frequently falling, the soil must be open indeed, if it be not constantly wet. The proportion of the different earths in a soil, therefore, must depend upon the quantity of rain which falls. In a rainy country, the soil ought to be open; in a dry country, it ought to be retentive of moisture. In the first, there ought to be a greater proportion of sand; in the second of clay.

Plants absorb food from the atmosphere;

2. That air is necessary for the vegetation of plants has been completely proven; and that a considerable portion at least of the carbonaceous matter which they contain is absorbed from the air, has been rendered probable by the late experiments of chemical philosophers. Three articles which furnish nourishment to plants are supplied by the atmosphere; namely, *carbonic acid*, *oxygen*, and *moisture*; but it has been disputed how far plants are capable of absorbing carbonic acid, without the assistance of the soil on which they usually vegetate.

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Hassenfratz analysed the bulbous roots of hya-s, in order to discover the quantity of water, car- and hydrogen, which they contained; and by re-ng the analysis on a number of bulbs, he disco- how much of these ingredients was contained in en weight of the bulb. He analysed also kidney and cress seeds in the same manner. Then he a number of each of these vegetate in pure water, g the precaution to weigh them beforehand, in to ascertain the precise quantity of carbon which contained. The plants being then placed, some in doors, and others in the open air, grew and red, but produced no seed. He afterwards dried , collecting with care all their leaves and every o- part which had dropt off during the course of the ation. On submitting each plant to a chemical sis, he found that the quantity of carbon which ined, was somewhat less than the quantity which ed in the bulb or the seed from which the plant prung *.

hese experiments have been lately repeated by sure with a very different result. Sprigs of *men- piperita*, allowed to vegetate for some time in distil- water, nearly doubled the portion of carbon which originally contained †; but when the same experi- t was repeated in a place where but little light had ss, the carbon, instead of being increased, was some- t diminished, as Hassenfratz had found. Hence it is able, that the result obtained by Hassenfratz was

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* *Ann. de Chim.* xiii. 188.

† *Recherches Chimiques sur la Vegetation*, p. 51.

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owing to the want of light. Thus it cannot be doubted, that plants, even when they vegetate in pure water, are capable of absorbing nourishment from the air; but as plants in this situation cannot produce perfect seeds, and as they gradually decay and cease to vegetate, it is obvious that water and air alone are not sufficient.

But this not sufficient.

3. The third, and only remaining source from which plants can draw their food, is the soil on which they grow. Now this soil consists of two parts; namely, *pure earths*, which constitute its basis, and the *remains* of animals and vegetables applied as manure.

One use of the earthy part of the soil is to furnish a support for the plants, and to administer the proper quantity of water to them; but as all plants contain earthy and saline matters, and as these substances are constantly present, we cannot avoid considering them as in some measure constituting an essential part of plants. Now there is reason to believe that the proportion of earthy and saline matters in plants is considerably influenced by the soil on which they vegetate. Saussure made beans grow in three different situations. The first set was supported by distilled water; the second was planted in sand and supported by rain water; the third set was planted in a pot filled with mould, and placed in a garden. The ashes yielded by these different plants were to each other in the following proportions *.

Proportion of earth in plants varies with the soil.

1. Those fed by distilled water.. 3·9
2. Those fed by rain water..... 7·5
3. Those growing in soil.......12·0

* *Recherches*, p. 281.

uantity of fixed matter yielded by the beans vegetated in soil, was more than three times an what was obtained from those which had lely by distilled water. Chap. III.

ne philosopher examined the ashes of various wing on a granitic and on a calcareous soil *. which grew in the granitic soil contained a le proportion of silica and metallic oxides; h grew in the calcareous, little or none of es, but a greater proportion of calcareous the granitic plants. Thus the pinus abies, t of each of these soils, yielded the following s of fixed bodies:

	Granitic.	Calcar.
....	3·60	15
ne sulphates and muriates	4·24	
ate of lime	46·34	63
ate of magnesia...........	6·77	 0
....	13·49	 0
na	14·86	16
ic oxides.....................	10·52	 0
	99·82	94 †

---

ils were composed of the following ingredients;

anitic.	Calcareous.
lica	98·000 carbonate of lime
lumina	0·625 alumina
me	0·625 oxide of iron
on and manganese	0·025 petroleum
	99·275

r. viii. 185.—*Jour de Phys.* lii. 27.—See the table of inci- ted in Vol. V. p. 167. of this Work, where the result of all nts of this philosopher is given.

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Thus it cannot be doubted, that the proportion of earthy matter contained in plants is considerably influenced by the nature of the soil on which they grow; but whether plants derive the whole of these fixed principles from the soil, or whether they are capable of forming them to a certain extent by the unknown powers of vegetation, are questions not yet finally decided. The experiments of Saussure would lead us to believe, that all the earths found in plants are absorbed from the soil; while those of Schræder seem to prove, that a portion of them is formed by vegetation, even when plants are so situated that they can derive no fixed principle from the soil on which they grow.

Whether plants generate earth.

The Berlin Academy proposed as a prize question, *To determine the earthy constituents of the different kinds of corn, and to ascertain whether these earthy parts are formed by the process of vegetation.* The prize was gained by Schræder, an apothecary in Berlin, and the result of his experiments was published by the Academy in 1800. He analysed the seeds of *wheat, rye, barley,* and *oats,* and ascertained the portion of earth which each contains. He analysed in the same manner rye-straw *. After having in this manner determined the proportion of earth which these seeds contained, he endeavoured to make them grow in some medium which could not furnish any earthy ingredient whatever. For a long time his attempts were baffled, every substance tried containing less or more of earth, and being therefore improper. At last he found that sulphur, in the state

Experiments of Schræder.

* The result of these analyses have been given in page 165. of this Volume.

of flowers, might be used with success, as it contained no earthy matter whatever, and as the seeds grew in it, and sent out their roots perfectly well, when it was properly moistened with water. The oxides of antimony and zinc were the substances which answered best after sulphur. The seeds, then, were planted in sulphur, placed in a garden at a distance from all dust, put into a box to which the light and the air had free access, but from which all dust and rain were carefully excluded, and they were watered with distilled water. The corn raised in this manner was found by Schræder to contain *more* earthy matter than had existed in the seeds from which it had grown *. Here, then, it would appear was the formation of earthy matter, unless we conceive that the air might have contained a sufficient quantity floating in it to furnish all that was found. Since the publication of his prize dissertation, Schræder has given to the public additional experiments on the same subject. In these he notices the trials of Saussure, and the results which were obtained from vegetables growing in calcareous and granitic soils; and particularly draws the attention of chemists to the fact ascertained by Saussure, that plants vegetating in a calcareous soil, which contained little or no silica, were yet found to yield a considerable portion of that earth †. Einhof likewise found in the ashes of a *pinus sylvestris*, which had grown in a soil that yielded no traces of lime, no less than 65 *per cent.* of that earth. He in-

* Braconnot's experiments agree with those of Schræder, but they were not made with the same precautions. See *Ann. de Chim.* lxi. 187.

† Gehlen's *Jour.* iii. 538.

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forms us also, that he has frequently observed the *lichen prunastri* and *ciliaris* encrusted in the months of August and September with a coat of carbonate of lime, when no lime was to be found in the neighbourhood, and when other plants were not encrusted in that manner *.

Saussure has observed very justly, that the absorption of earthy matter does not depend so much upon the earths which constitute the basis of the soil on which they grow, as upon the portion of earth held in solution in the liquid part of the soil. This observation will explain several of the facts above stated, but is by no means sufficient to set aside the experiments of Schræder, which go directly to prove that earths are formed by the processes of vegetation.

Soil contains salts,

4. Besides earths, plants always contain a portion of saline matter. Those that grow at a distance from the sea contain potash, while sea-plants contain soda and common salt. Phosphate of lime is a constant ingredient, and phosphate of potash a very common one. Some plants contain peculiar salts. Thus nitrate of soda is usually present in barley, nitrate of potash in nettles and the sun-flower, &c. It appears, from the experiments that have been made, that peculiar salts promote the vegetation of peculiar plants. Sea-plants require common salt, and languish in soils where it is not to be found. Borage, nettles, and pellitory, thrive only in soils which contain nitrate of lime or potash; gypsum promotes the vegetation of lucern and clover†.

Which act on plants.

Salts then are not inactive; and when properly ap-

* Gehlen's *Jour.* iii. 563.

† Saussure, *Recherches*, p. 264

plied, they promote the growth of vegetables. In these cases they appear to be absorbed by the plants which they invigorate. Duhamel found that sea-plants made little progress in soils which contain no common salt. Bullion made seeds of sun-flower to grow in a sandy soil containing no trace of nitre. On examining the plants, no nitrate of potash could be detected in them, but the salt made its appearance as usual when the plants were watered with a weak nitrous solution.

Plants absorb different proportions of salts.

From the experiments of Saussure, we learn that plants absorb saline solutions in very different proportions, and that in general those are absorbed in greatest quantity which are most injurious to vegetation. He dissolved the following substances in water, in such proportions, that each solution contained $\frac{1}{100}$th part of its weight of the substance dissolved, except the last, which contained $\frac{1}{11}$th part.

1. Muriate of potash
2. Muriate of soda
3. Nitrate of lime
4. Sulphate of soda effloresced
5. Muriate of ammonia
6. Acetate of lime
7. Sulphate of copper
8. Crystals of sugar
9. Gum arabic
10. Extract of soil

Into each of these solutions he put plants of *polygonum persicaria*, or of *bidens cannabina*, furnished with their roots.

The polygonum grew for five weeks in the solutions of muriate of potash, nitrate of lime, muriate of soda, sulphate of soda, and extract of soil; and the

roots increased in them as usual. It languished in the solution of sal-ammoniac, and the roots made no progress. It died in eight or ten days in the solutions of gum and of acetate of lime, and in less than three days in the solution of sulphate of copper.

When such a number of plants of polygonum were put into the solutions as to absorb one half of each in two days, the remaining half was found to have lost very different proportions of the salt which it had originally contained. Suppose the portion of salt originally in solution to be 100, the following Table exhibits the quantity of each which had disappeared when one half of the liquid was absorbed:

Muriate of potash	14·7
Muriate of soda	13
Nitrate of lime	4
Sulphate of soda	14·4
Muriate of ammonia	12
Acetate of lime	8
Sulphate of copper	47
Sugar	29
Gum	9
Extract of soil	5

The *bidens* absorbed pretty much the same proportions, but in general did not vegetate so long as the polygonum. In these trials, it was the sulphate of copper and the sugar that were absorbed in greatest abundance, and these were the substances which proved most injurious to the plant. Saussure explains this apparent anomaly by supposing that a portion of the roots were soon destroyed in these liquids, and that then they absorbed the solution indiscriminately.

When various salts were dissolved at once in the

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e solutions, and plants made to vegetate in them, it found that different proportions of the salts were orbed. The following Table exhibits the result of se trials, supposing, as before, the original weight ach salt to have been 100. Each solution contain- $\frac{1}{500}$th part of its weight of each salt.

Solutions	Salts.	Salt absorbed.
1	Sulphate of soda effloresced Muriate of soda	11·7 22·0
2	Sulphate of soda effloresced Muriate of potash	12 17
3	Acetate of lime Muriate of potash	8' 33
4	Nitrate of lime Muriate of ammonia	4·5 16·5
5	Acetate of lime Sulphate of copper	31 34
6	Nitrate of lime Sulphate of copper	17 34
7	Sulphate of soda Muriate of soda Acetate of lime	6 10 0
8	Gum Sugar	26 34

These experiments succeeded nearly equally with her plants, as *the mentha piperita* and the Scotch fir.

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When the roots were cut or removed, the plants absorbed all solutions indiscriminately. On examining the plants, the salts absorbed were found in them unaltered *.

Thus it appears that plants do not absorb saline bodies indiscriminately. Saussure supposes that the difference depends rather upon the degree of liquidity which the solution possesses, than upon any discriminating power in the root. But if this were the case, it would be difficult to explain how so much greater a proportion of water should be absorbed than of the salt which it holds in solution.

Manure necessary for the growth of plants.

5. Water, then, carbonic acid, and oxygen, and perhaps also earths and salts, constitute a part of the food of plants; but it is very clear that the whole food is not furnished by these substances. It is well known, that if vegetables be successively raised on the same ground, they at last exhaust it, or render it sterile; and to prevent this, farmers are obliged to supply their grounds annually with a quantity of manure. Without this manure, or some equivalent, plants cannot be made to thrive, or to perfect their seeds. Neither water, air, nor earths, nor salts, will prevent them from perishing. Giobert mixed together the four earths, silica, alumina, lime, and magnesia, in the proper proportions to constitute a fertile soil; and after moistening them with water, planted several vegetables in them: but none of them grew well till he moistened his soil with water from a dunghil. Lampadius planted different vegetables in compartments of his garden, filled each

* Saussure, *Recherches*, p. 247, 261.

with one of the pure earths, and watered them with the liquor which exuded from a dunghill. They all grew, notwithstanding the diversity of the soil; and each contained the usual earthy constituents of plants, notwithstanding the absence of these constituents from the soil. Chap. III.

It is not the earths which constitute a fertile soil, but the remains of animal and vegetable substances, and the proportion of these capable of being held in solution by water. It appears from the experiments of Mr Hassenfratz, that substances employed as manures produce effects in times proportioned to their degree of putrefaction; those substances which are most putrid producing the most speedy effects, and of course soonest losing their efficacy. Having manured two pieces of the same kind of soil, the one with a mixture of dung and straw highly putrefied, the other with the same mixture newly made, and the straw almost fresh, he observed, that during the first year, the plants which grew on the land manured with the putrefied dung produced a much better crop than the other: but the second year (no new dung being added), the ground which had been manured with the unputrefied dung produced the best crop; the same thing took place the third year; after which, both seemed to be equally exhausted *. Here it is evident that the putrefied dung acted soonest, and was soonest exhausted. It follows from this, that carbon only acts as a manure when in a particular state of combination; and this state, whatever it may be, is evidently produced by putrefaction. Another experi-

* *Ann. de Chim.* xiv. 57.

Book IV. ment of the same chemist renders this truth still more evident. He allowed shavings of wood to remain for about ten months in a moist place till they began to putrefy, and then spread them over a piece of ground by way of manure. The first two years this piece of ground produced nothing more than others which had not been manured at all; the third year it was better, the fourth year it was still better, the fifth year it reached its maximum of fertility; after which it declined constantly till the ninth, when it was quite exhausted*. Here the effect of the manure evidently depended upon its progress in putrefaction.

Vegetable manure.

When vegetables are allowed to putrefy in the open air, they are converted into a loose black substance, well known under the name of *vegetable mould*. On this mould plants grow with great vigour. It is the substance which renders newly cultivated lands in America, &c. so fertile. When exposed to the air, in the course of cultivation, it is gradually wasted and destroyed, and the lands are thus impoverished. This vegetable mould, therefore, is obviously one of the grand sources of the food of plants. It deserves, therefore, an accurate examination.

Its properties.

To Saussure and Einhof we are indebted for a chemical examination of its properties and constituents. Saussure employed in his experiments pure vegetable soil, which he procured either from the trunks of trees or from elevated rocks, where it was unmixed with any animal matter; and by passing it through a searce, he removed from it the remains of undecayed vege-

* *Ann. de Chim.* xiv. p. 58.

tables with which it was mixed *. By distilling 200 grains (French) of mould from the oak, he obtained the following products; while the same quantity of undecayed oak yielded him the following proportions of the same constituents.

	Mould.	Oak.
Carbureted hydrogen gas	124 inches (French)	116
Carbonic acid	34	29
Water, containing pyrolignate of ammonia	53 grains (French)	80
Empyreumatic oil	10	13
Charcoal	51	41½
Ashes	8	0¼

Nearly the same results were obtained by making similar experiments on other vegetables, and the mould which they yield when decayed. It appears from them, that the mould contains more charcoal, weight for weight, than the vegetables from which it proceeded. It yields also more ammonia, and therefore contains more azote.

Acids do not act powerfully on mould. Alcohol takes up a portion of extractive and resin. The fixed alkalies dissolve it almost completely, and ammonia is disengaged during the solution. Acids throw down a small portion of a brown combustible powder. Water dissolves a portion of extractive; but the quantity is small, especially from the mould of fertile soils. 10 parts of water, left for five days on the mould of turf, were found to have dissolved only 26 parts of it; and the same quantity, left on the soil of a

* *Recherches sur la Vegetation*, p. 162.

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field which bore a fine crop of wheat, was found to have dissolved but four parts. It appears from the experiments of Saussure, that a mould which yielded to boiling water, by repeated decoctions, $\frac{1}{11}$th of its weight of extract, did not produce so good an effect upon beans as a mould which contained only half that quantity of soluble matter. But when mould is deprived of its soluble part by boiling water, though its appearance is not altered, yet it does not support plants nearly so well as mould which has not been thus exhausted *.

The extract thus obtained from mould by Saussure did not deliquesce when exposed to the air. When distilled it yielded carbonate of ammonia. It produced no change on vegetable blues. When reduced to the consistence of a syrup it had a sweet taste ; it precipitated by exposure to the air, and became turbid when mixed with lime-water, carbonate of potash, and most metallic solutions. Alcohol dissolves only a portion of it, and this part is very deliquescent †.

And constituents.

From the experiments of Einhof, it appears that the extract obtained from mould possesses very nearly the properties of the *extractive principal.* The mould which he employed in his experiments was from the soil of a wood, and had been formed by the leaves of the trees and the putrefied herbs. It was black, firm, produced no change on vegetable blues, and contained no undecayed plants ‡. Water in which this mould was boiled was at first colourless ; but by exposure to the

* *Recherches*, p. 170. † Ibid. p. 174.
‡ Gehlen's *Jour.* vi. 373.

acquired a brownish tint. The substance which d in solution possessed exactly the charact r, of tive.

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periments upon vegetable mould have been made by Braconnot. He found no portion of it soluble ter. His other results resembled those of Saus- When an alkaline ley was boiled with mould ion was dissolved. The residue had the exact rance of pit coal *.

Acid vegetable mould.

ides this fertile vegetable mould, Einhof has ex- d another of a different nature, to which he has the name of *acid vegetable mould*. It occurs in ing meadows and marshes, and the plants which upon it in these situations are the different species *ex*, *juncus*, and *eriophorum*. It constitutes also incipal part of the mould in high-lying situations, oors where the soil is covered with heath (*erica is*). This mould is distinguished from the pre- by containing a notable portion of phosphoric etic acids, which give it the property of redden- getable blues. The extractive which it contains efly insoluble in water†. This sour vegetable bears a considerable resemblance to peat, into indeed it probably passes. Like it, peat con- portion of phosphoric acid, and probably also tic acid, and an extractive readily soluble in al- though but sparingly in water ‡.

Effect of lime on mould.

hof has observed, that acid vegetable mould ne- curs in those soils which abound in lime, and that

* *n. de Chim.* lxi. 191.

† Gehlen, vi. 379.

‡ nhof, Gehlen's *Jour.* iii. 400.

sists of an examination of the excrements of black cattle *; and the second, by Berzelius, is upon the human excrementitious matter †. These add considerably to our knowledge of animal substances, and shall therefore be noticed in a subsequent part of this Work; but as they throw little light on the use of these matters as manures, it is unnecessary to give a detail in this place of the constituents of which they found them composed.

Food absorbed by the ends of the roots.

Such is the present state of our knowledge respecting the food of plants, as far as it is supplied by the soil in which they vegetate. It is probable that it is imbibed by the extremities of the roots only; for Duhamel observed, that the portion of the soil which is soonest exhausted is precisely that part in which the greatest number of the extremities of roots lies ‡. This shows us the reason why the roots of plants are continually increasing in length. By this means they are enabled, in some measure, to go in quest of nourishment. The extremities of the roots seem to have a peculiar structure adapted for the imbibing of moisture. If we cut off the extremity of a root, it never increases any more in length: therefore its use as a root has been in a great measure destroyed. But its sides send out fibres which act the part of roots, and imbibe food by their extremity. Nay, in some cases, when the extremity of a root is cut off, the whole decays, and a new one is formed in its place. This, as Dr Bell informs us, is the case with the hyacinth §.

It must be in a state of solution.

The extremities of the roots contain no visible open-

* Gehlen's *Jour.* iii. 276.

† Ibid. vi. 509.

‡ *Physique des Arbres*, ii. 239.

§ *Manch. Mem.* ii. 412.

Book IV. ing. Hence we may conclude that the food which they imbibe, whatever it may be, must be in a state of solution; while the absolute necessity of water renders it probable that water is the solvent. And, in fact, the carbonaceous matter in all active manures is in such a state of combination that it is soluble in water. All the salts which we can suppose to make a part of the food of plants are more or less soluble in water. This is the case also with lime, whether it be pure or in the state of a salt; magnesia and alumina may be rendered so by means of carbonic acid gas; and Bergman, Macie, and Klaproth, have shown that even silica may be dissolved in water. We can see, therefore, in general, though we have no precise notions of the very combinations which are immediately imbibed by plants, that all the substances which form essential parts of that food *may* be dissolved in water.

SECT. III.

OF THE MOTION OF THE SAP.

SINCE the food of plants is imbibed by their roots in a fluid state, it must exist in plants in a fluid state; and unless it undergoes alterations in its composition just when imbibed, we may expect to find it in the plant unaltered. If there were any method of obtaining this fluid food from plants before it has been altered by them, we might analyse it, and obtain by that means a

much more accurate knowledge of the food of plants than we can by any other method. This plan indeed must fail, provided the food undergoes alteration just when it is absorbed by the roots: but if we consider, that when one species of tree is grafted upon another, each bears its own peculiar fruit, and produces its own peculiar substances, we can scarcely avoid thinking that the *great* changes at least, which the food undergoes after absorption, are produced, not in the roots, but in other parts of the plant.

Sap of plants.

If this conclusion be just, the food of plants, after being imbibed by the roots, must go directly to those organs where it is to receive new modifications, and to be rendered fit for being assimilated to the different parts of the plant. There ought therefore to be certain juices continually ascending from the roots of plants; and these juices, if we could get them pure and unmixed with the other juices or fluids which the plant must contain, and which have been secreted and formed from these primary juices, would be, very nearly at least, the food as it was imbibed by the plant. Now, during the vegetation of plants, there actually is a *juice* continually ascending from their roots. This juice has been called the *sap*, the *succus communis*, or the *lymph* of plants.

Flows out in the spring.

The sap is most abundant during the spring. At that season, if a cut be made through the bark and part of the wood of some trees, the sap flows out very profusely. The trees are then said to *bleed*. By this contrivance any quantity of sap we think proper may be collected. It is not probable, indeed, that by this method we obtain the ascending sap in all its purity; it is no doubt mixed with the peculiar juices of the plant:

Book IV. but the less progress vegetation has made, the purer we may expect to find it; both because the peculiar juices must be in much smaller quantity, and because its quantity may be supposed to be greater. We should therefore examine the sap as early in the season as possible, and at all events before the leaves have expanded.

Though a number of experiments, as we have seen in the last Chapter, have been made upon the sap, they are not of such a nature as to throw much light upon the food absorbed by plants. Chemistry has not made such progress as to enable even the most expert analysts to separate and distinguish small quantities of vegetable matter. It is even possible that the food, after it has been imbibed, may be, to a certain extent, modified and altered by the roots. In what manner this is done we cannot say, as we know very little about the vascular structure of the roots. We may conclude, however, that this modification is nearly the same in most plants: for one plant may be engrafted on another, and each continue to produce its own peculiar products; which could not be, unless the proper substances were conveyed to the digestive organs of all. There are several circumstances, however, which render the modifying power of the roots somewhat probable. It is even possible that the roots may, by some means or other, throw out again some part of the food which they have imbibed as excrementitious. This has been suspected by several physiologists; and there are several circumstances which render it probable. It is well known that some plants will not vegetate well after others; and that some again vegetate unusually well when planted in ground where certain plants had been

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growing. These facts, without doubt, may be accounted for on other principles. If there be any excrementitious matter emitted by the roots, it is much more probable that this happens in the last stage of vegetation; that is to say, when the food, after digestion, is applied to the purposes which the root requires. But the fact ought to be supported by experiments, otherwise it cannot be admitted.

Mixed with true sap in its ascent.

Mr Knight, to whose ingenious and important experiments and observations vegetable physiology lies under so many obligations, has rendered it extremely probable, that the sap, as it ascends, is mixed with a quantity of matter, previously deposited in the alburnum for that purpose, and ready prepared to be assimilated to the different vegetable organs *. According to him, plants, after they have attained their full growth, are employed during the latter part of summer in preparing food for the expanding of the buds and blossoms in the succeeding spring. This food when prepared is deposited in the alburnum. Here it continues during the winter, and in next spring, mixing with the ascending sap, it affords nourishment to the buds and leaves. This ingenious opinion Mr Knight has supported by experiments and observations, sufficient, I think, to establish its truth. It constitutes a very important step in vegetable physiology, as it enables us to explain many circumstances in a satisfactory manner that appeared formerly altogether anomalous.

He ascertained, by experiments, that the sap increases

* *On the State in which the True Sap of Trees is deposited during Winter.* Phil. Trans. 1805.

in density as it ascends towards the leaves. Sap extracted from the sycamore, close to the ground, was of the specific gravity 1·004; while that which flowed out at the height of seven feet was 1·008, and at the height of 12 feet 1·012. The sap of the birch was somewhat lighter, but its comparative increase of density, according to its height, was the same. When extracted near the ground, the sap, both of the sycamore and birch, was nearly tasteless; but it became sensibly sweet at some height, and the sweetness increased with the distance from the ground. Thus it appears, that the quantity of vegetable matter in sap increases as it flows towards the leaves; a direct proof that it imbibes and mixes with something during its passage. That this matter was lodged in the alburnum was rendered probable by comparing with each other the alburnum in winter and in summer. For if nutriment be laid up in the alburnum in winter, and employed in summer for the purposes of vegetation, it is obvious that the alburnum during winter ought to be denser, and ought to yield more extract to water, than the same substance in summer: both of which Mr Knight found to be the case. Oak poles, of the same age, and growing from the same stool, were felled, partly in December and partly in May. They were placed in the same situation, and dried for seven weeks by a fire. The specific gravity of the winter felled wood was 0·679, of the summer 0·609. When the alburnum alone was weighed, the specific gravity of the winter felled was 0·583; of the summer felled 0·533. 1000 grains of each being mixed with six ounces of boiling water, and left to macerate for 24 hours, the winter felled infusion was much deeper coloured than the other. Its specific gravity

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was 1·002; while that of the summer felled infusion was 1·001. This deposition of nutritious matter explains why the alburnum of trees felled in winter is much more solid and valuable than the alburnum of trees felled in summer.

The sap, as Dr Hales has shown us, ascends with a very considerable force. It issued during the bleeding season with such impetuosity from the cut end of a vine branch, that it supported a column of mercury 32½ inches high *.

Now, what is the particular channel through which the sap ascends, and what is the cause of the force with which it moves? These are questions which have excited a great deal of the attention of those philosophers who have made the physiology of vegetables their particular study; but the examination of them is attended with so many difficulties that they are very far from being decided.

Sap ascends.

It is certain that the sap flows from the roots towards the summit of the tree. For if in the bleeding season a number of openings be made in the tree, the sap begins first to flow from the lowest opening, then from the lowest but one, and so on successively, till at last it makes its appearance at the highest of all; and when Duhamel and Bonnet made plants vegetate in coloured liquors, the colouring matter, which was deposited in the wood, appeared first in the lowest part of the tree, and gradually ascended higher and higher, till at last it reached the top of the tree, and tinged the very leaves.

* *Veg. Stat.* i. 105.

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Through the wood.

It seems certain too that the sap ascends through the wood, and not through the bark of the tree: for a plant continues to grow even when stript of a great part of its bark; which could not happen if the sap ascended through the bark. When an incision, deep enough to penetrate the bark, and even part of the wood, is carried quite round a branch, provided the wound be covered up from the external air, the branch continues to vegetate as if nothing had happened; which could not be the case if the sap ascended between the bark and the wood. It is well known, too, that in the bleeding season little or no sap can be got from a tree unless our incision penetrate deeper than the bark.

These conclusions have been confirmed by the experiments made lately by Coulomb and Knight. Coulomb observed that no sap ever flows from the poplar till the tree be cut nearly to the centre *. Mr Knight observed that coloured infusions always pass through the alburnum, and that whenever the alburnum is cut through the plant dies †.

In peculiar vessels.

As the sap is never found in the parenchyma, it must of necessity be confined in particular vessels; for if it were not, it would undoubtedly make its appearance there. Now, what are the vessels through which the sap ascends?

Grew and Malpighi, the first philosophers who examined the structure of plants, took it for granted that the woody fibres were tubes, and that the sap ascended through them. For this reason they gave these fibres the name of *lymphatic vessels*. But they were unable,

* *Jour. de Phys.* xlix. 392 † *Phil. Trans.* 1801, p. 336.

n assisted by the best microscopes, to detect in these fibres which had the appearance of a d succeeding observers have been equally un-l. The conjecture therefore of Malpighi and out the nature and use of these fibres, remains supported by any proof. Duhamel has even to overturn it altogether: for he found that dy fibres are divisible into smaller fibres, and in into still smaller; and even, by the assist-he best microscopes, he could find no end of vision *. Now, granting these fibres to be t is scarcely possible, after this, to suppose ap really moves through tubes, whose diame-most infinitely small. There are, however, plants which may easily be distinguished by f a small microscope, and even in many cases ked eye. These were seen, and distinctly de-y Grew and Malpighi. They consist of a ted round like a corkscrew. If we take a inder of wood, and wrap round it a slender , so closely that all the rings of the wire touch , and if, after this, we pull out the wooden altogether, the brass wire thus twisted will very good representation of these vessels. If old of the two ends of the brass wire thus nd pull them, we can easily draw out the wire derable length. In the same manner, when ld of the two extremities of these vessels, we them out to a great length. Malpighi and ding them always empty, concluded that they

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* *Physique des Arbres*, i. 57.

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were intended for the circulation of the air through the plant, and therefore gave them the name of *tracheæ*; which word is used to denote the *windpipe* of animals. These *tracheæ* are not found in the bark; but Hedwig has shown that they are much more numerous in the wood than was supposed; and that they are of very different diameters; and Reichel has demonstrated that they go to the minutest branches, and spread through every leaf. He has shown, too, that they contain sap; and Hedwig has proved that the notion which generally prevailed of their containing nothing but air, arose from this circumstance, that the larger *tracheæ*, which alone were attended to, lose their sap as soon as they are cut; and of course, unless they are inspected the instant they are divided, they appear empty *. Is it not probable, then, from the discoveries of that very ingenious physiologist, that the tracheæ are, in reality, the sap vessels of plants? Indeed it seems established, by the experiments both of Reichel and Hedwig, that almost all the vessels of plants may, if we attend only to their structure, be denominated *tracheæ*. But whether the structure of the sap vessels be similar to that of the tracheæ or not, it has been perfectly ascertained that the sap ascends in vessels, and that these vessels are situated in the wood, chiefly indeed in the alburnum. Hence Mr Knight has given them the name of *alburnous* vessels.

Its ascension

But by what powers is the sap made to ascend in these vessels? and not only to ascend, but to move with very considersble force; a force, as Hales has shown,

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* *Fundament. Hist. Nat. Muscor. Frondos.* Part I. p. 54.

to overcome the pressure of 43 feet perpendi- water *? Chap. III.

ascribed this phenomenon to the levity of the ich, according to him, entered the plant in the a very light vapour. But this opinion will not slightest examination. Malpighi supposed sap was made to ascend by the contraction and of the air contained in the air vessels. But re we to grant that the tracheæ are air vessels, according to this hypothesis, could only ascend change of temperature takes place; which is to fact. And even if we were to wave every of that kind, the hypothesis would not ac- the circulation of the sap, unless the sap ves- rovided with valves. Now the experiments of d Duhamel show that no valves can possibly them: For branches imbibe moisture nearly by either end; and consequently the sap moves al facility both upwards and downwards, which not do were there valves in the vessels. Be- is known, from many experiments, that we vert the roots of a tree into the branches, and ches into the roots, by covering the branches th, and exposing the roots to the air †. Now ld be impossible if the sap vessels were provi- valves. The same remarks overturn the hy-

Ascribed to its levity;

To the contraction of air;

* *Stat.* i. 107.

† night has lately shown that the inverted shoots by no means ll as when in their natural position; and has even made it at the vessels of the bark are furnished with valves, or with equivalent. But no evidence has been adduced to induce us hat this is the case with the sap vessels.—See his *Observations on of the Sap of Trees. Phil. Trans.* 1804.

pothesis of Mr de la Hire, which is merely that of Malpighi, expressed with greater precision, and with a greater parade of mechanical knowledge. Like Borelli, he placed the ascending power of the sap in the parenchyma. But his very experiments, had he attended to them with care, would have been sufficient to show the imperfection of his theory.

The greater number of philosophers (for it is needless to mention those who, like Perrault, had recourse to fermentation, nor those who introduced the weight of the atmosphere) have ascribed the motion of the sap to *capillary attraction*.

To capillary attraction,

There exists an attraction between many solid bodies and liquids; in consequence of which, if these solid bodies be formed into small tubes, the liquid enters them, and rises in them to a certain height. But this is perceptible only when the diameter of the tube is very small. Hence the attraction has been denominated *capillary*. We know that there is such an attraction between vegitable fibres and watery liquids; for such liquids will ascend through dead vegetable matter. It is highly probable, therefore, that the food of plants enters the roots, in consequence of the capillary attraction which subsists between the sap vessels and the liquid imbibed. This species of attraction, then, will account perfectly well for the entrance of moisture into the mouths of the sap vessels: But will it account also, as some have supposed, for the ascent of the sap, and for the great force with which it ascends?

The nature and laws of ca[illegible] attraction have been
very much overlooked by
enough concerning it to en
question. It consists in

the particles of the liquid and of the tube. It has been demonstrated, that it does not extend, or at least that it produces no sensible effect, at greater distances than $\frac{1}{1000}$th part of an inch. It has been demonstrated, that the water ascends, not by the capillary attraction of the whole tube, but of a slender film of it; and Clairaut has shown that this film is situated at the lowermost extremity of the tube *. This film attracts the liquid with a certain force; and if this force be greater than the cohesion between the particles of the liquid, part enters the tube, and continues to enter, till the quantity above the attracting film of the tube just equals, by its weight, the excess of the capillary attraction between the tube and the liquid above the cohesion of the liquid. The quantity of water, therefore, in the tube is pretty nearly the measure of this excess; for the attracting film is probably very minute.

But without reason.

It has been demonstrated, that the heights to which liquids rise in capillary tubes, are inversely as the diameter of the tube. Consequently the smaller the diameter of the tube, the greater is the height to which the liquid will rise. But the particles of water are not infinitely small; therefore, whenever the diameter of the tube is diminished beyond a certain size, water cannot ascend in it, because its particles are now larger than the bore of the tube. Consequently the rise of water

* The action of all the other films, of which the tube is composed, on the water, as far as it is measured by its effect, is nothing at all. For [illegible] particle of water in the tube (except those attracted by the under[illegible]n) is attracted upwards and downwards by the same number of [illegible] is therefore precisely in the same state as if it were not attracted

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in capillary tubes must have a limit: if they exceed a certain length, how small soever their bore may be, water will either not rise to the top of them, or it will not enter them at all. We have no method of ascertaining the precise height to which water would rise in a capillary tube, whose bore is just large enough to admit a single particle of water. Therefore we do not know the limit of the height to which water may be raised by capillary attraction. But whenever the bore is diminished beyond a certain size, the quantity of water which rises in it is too small to be sensible. We can easily ascertain the height which water cannot exceed in capillary tubes before this happens; and if any person calculate, he will find that this height is not nearly equal to the length of the sap vessels of many plants. But besides all this, we see in many plants very long sap vessels, of a diameter too large for a liquid to rise in them a single foot by capillary attraction, and yet the sap rises in them to very great heights.

If any person says that the sap vessels of plants gradually diminish in diameter as they ascend; and that, in consequence of this contrivance, they act precisely as an indefinite number of capillary tubes, one standing upon another, the inferior serving as a reservoir for the superior—I answer, that the sap may ascend by that means to a considerable height: but certainly not in any greater quantity than if the whole sap vessel had been precisely of the bore of its upper extremity; for the quantity of sap raised must depend upon the bore of the upper extremity, because it must all pass through that extremity.

But farther, if the sap m[illegible] only in the vessels of plants by capillary attrac[illegible]uld be so far from

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flowing out at the extremity of a branch, with a force sufficient to overcome the pressure of a column of water 43 feet high, that it could not flow out at all. It would be impossible in that case for any such thing as the bleeding of trees ever to happen.

If we take a capillary tube, of such a bore that a liquid will rise in it six inches, and after the liquid has risen to its greatest height, break it short three inches from the bottom, none of the liquid in the under half flows over. The tube, thus shortened, continues indeed full, but not a single particle of liquid ever escapes from it. And how is it possible for it to escape? The film, at the *upper* extremity of the tube, must certainly have as strong an attraction for the liquid as the film at the *lower* extremity. As part of the liquid is within its attracting distance, and as there is no part of the tube above to counterbalance this attraction, it must of necessity attract the liquid nearest it, and with a force sufficient to counterbalance the attraction of the undermost film, how great soever we may suppose it. Of course no liquid can be forced up, and consequently none can flow out of the tube. Since, then, the sap *flows out* at the upper extremity of the sap vessels of plants, we are absolutely certain that it does not ascend in them merely by its capillary attraction, but that there is some other cause.

It is impossible, therefore, to account for the motion of the sap in plants by any mechanical or chemical principles whatever; and he who ascribes it to these principles has not formed to himself any clear or accurate conception of the subject. We know indeed that heat is an agent; for Dr Walker found that the ascent [of t]he sap is much promoted by heat, and that after it

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had begun to flow from several incisions, cold made it give over flowing from the higher orifices while it continued to flow at the lower *. But this cannot be owing to the dilating power of heat; for unless the sap vessels of plants were furnished with valves, dilatation would rather retard than promote the ascent of the sap.

The vessels must contract.

We must, therefore, ascribe it to some other cause: the vessels themselves must certainly act. Many philosophers have seen the necessity of this, and have accordingly ascribed the ascent of the sap to *irritability*. But the first person who gave a precise view of the manner in which the vessels probably act was Saussure. He supposes that the sap enters the open mouths of the vessels at the extremity of the roots; that these mouths then contract, and by that contraction propel the sap upwards; that this contraction gradually follows the sap, pushing it up from the extremity of the root to the summit of the plant. In the mean time the mouths are receiving new sap, which in the same manner is pushed upwards †. Whether we suppose the contraction to take place precisely in this manner or not, we can scarcely deny that it must take place; but by what means it is impossible at present to say. The agents cannot precisely resemble the muscles of animals; because the whole tube, however cut or maimed, still retains its contracting power, and because the contraction is performed with equal readiness in every direction ‡.

* *Edin. Trans.* i.

† [illegible]*cycl. Meth. Phys. Veget.* p. 267.

‡ Mr Knight thinks it prob[illegible]e sap is propelled by the contraction and expansion of wha[illegible] car[illegible] *silver grain of*

It is evident, however, that they must be the same in kind. Perhaps the particular structure of the vessels may fit them for their office. Does ring after ring contract its diameter? The contracting agents, whatever they are, seem to be excited to act by some stimulus communicated to them by the sap. This capacity of being excited to action is known in physiology by the name of *irritability*; and there are not wanting proofs that plants are possessed of it. It is well known that different parts of plants move when certain substances act upon them. Thus the flowers of many plants open at sunrise, and close again at night. Linnæus has given us a list of these plants. Des Fontaines has shown that the stamina and antheræ of many plants exhibit distinct motions *. Dr Smith has observed, that the stamina of the barberries are thrown into motions when touched †. Roth has ascertained that the leaves of the *drosera longifolia* and *rotundifolia* have the same property. Mr Coulomb, too, who has adopted the opinion that the motion of the sap in plants is produced by the contraction of vessels, has even made a number of experiments in order to show this contraction. But the fact is, that every one has it in his power to make a decisive experiment. Simply cutting a plant, the *euphorbia peplis* for instance, in two places, so as to separate a portion

the wood, between the laminæ of which the vessels run. (*Phil. Trans.* 1801, p. 344.) By *silver grain* is meant those thin longitudinal fibres, diverging in every direction from the pith, and composed of the lymphatic vessels of Grew and Malpighi. I do not see how the contraction of these laminæ could propel the sap through the sap vessel, destitute as they are of valves, unless it were a contraction precisely similar to what Saussure supposed to take place in the sap vessels.

* *Mem. Par.* 1787.

† *Phil. Trans.* lxxviii.

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of the stem from the rest, is a complete demonstration that the vessels actually do contract. For whoever makes the experiment, will find that the milky juice of that plant flows out at both ends so completely, that if afterwards we cut the portion of the stem in the middle no juice whatever appears. Now it is impossible that these phenomena could take place without a contraction of the vessels; for the vessels in that part of the stem which has been detached cannot have been more than full; and their diameter is so small, that if it were to continue unaltered, the capillary attraction would be more than sufficient to retain their contents, and consequently not a drop would flow out. Since, therefore, the whole liquid escapes, it must be driven out forcibly, and consequently the vessels must contract.

It seems pretty plain, too, that the vessels are excited to contract by various stimuli; the experiments of Coulomb and Saussure render this probable, and an observation of Dr Smith Barton makes it next to certain. He found that plants growing in water vegetated with much greater vigour, provided a little camphor was thrown into the water *.

* *Ann. de Chim.* xxiii. 63.

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OF THE FUNCTIONS OF THE LEAVES.

s been ascertained that the sap ascends to the that it there undergoes certain alterations, and erted into another fluid called the *succus propri- uliar juice*, or *true sap*; which, like the blood in s, is afterwards employed in forming the various ices found in plants. Now, the changes which undergoes in the leaves, provided we can trace must throw a great deal of light upon the nature etation. These changes are produced in part the day, in part during the night. Now, as the ns of the leaves during the day are very different vhat they are during the night, it will be proper ider them separately.

Peculiar juice formed by the leaves.

Vo sooner has the sap arrived at the leaves, than part of it is thrown off by evaporation.

Part of the sap transpires.

The quantity thus perspired bears a very great tion to the moisture imbibed. Mr Woodward that a sprig of mint, weighing 27 grains, in 77 mbibed 2558 grains of water, and yet its weight nly increased 15 grains; therefore it must have out 2543 grains. The same experiment was re- l by this philosopher on other plants; the follow- able exhibits the result *:

Its quantity.

* *Phil. Trans.* 1699. xxix, 193.

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Plants and Water.	Weight.		Gain in 77 days.	Water wasted.
	When put in	When taken out.		
	gr.	gr.	gr.	gr.
Spearmint in spring water	27	42	15	2558
Spearmint in rain water	$28\frac{1}{2}$	$45\frac{3}{4}$	$17\frac{1}{2}$	3004
Spearmint in Thames water	28	54	26	2493
Common nightshade in spring water	49	106	57	3708
Lathyris in spring water	98	$101\frac{1}{2}$	$3\frac{1}{2}$	2501

These experiments demonstrate the great quantity of matter which is constantly leaving the plant. Dr Hales found that a cabbage transmitted daily a quantity of moisture equal to about half its weight; and that a sun-flower, three feet high, transmitted in a day 1 lb. 14 oz. avoirdupois †. He showed, that the quantity of transpiration in the same plant was proportional to the surface of the leaves, and that when the leaves were taken off the transpiration nearly ceased ‡. By these observations, he demonstrated that the leaves are the organs of transpiration. He found, too, that the transpiration was nearly confined to the day, very little taking place during the night §; that it was much promoted by heat, and stopped by rain and frost *: and Millar ||, Guettard ¶, and Sennebier, have shown that the transpiration is also very much promoted by sunshine.

The quantity of moisture imbibed by plants depends

† *Veget. Stat.* i. 5. and 15.
‡ Ibid. p. 30.
§ Ibid. p. 5.
* Ibid. p. 27. and 48.
|| Ibid. p. 22.
¶ *Mem. Par.* 1748.

very much upon what they transpire: The reason is evident: when the vessels are once filled with sap, if none be carried off, no more can enter; and, of course, the quantity which enters must depend upon the quantity emitted.

Nature of the perspired matter.

2. In order to discover the nature of the transpired matter, Hales placed plants in large glass vessels, and by that means collected a quantity of it *. He found that it resembled pure water in every particular, excepting only that it sometimes had the odour of the plant. He remarked, too, as Guettard and Duhamel did after him, that when kept for some time it putrefied, or at least acquired a stinking smell. Sennebier subjected a quantity of this liquid to a chemical analysis.

He collected 13030 grains of it from a vine during the months of May and June. After filtration he gradually evaporated the whole to dryness. There remained behind two grains of residuum. These two grains consisted of nearly $\frac{1}{2}$ grain of carbonate of lime, $\frac{1}{12}$ grain of sulphate of lime, $\frac{1}{2}$ grain of matter soluble in water, and having the appearance of gum, and $\frac{1}{2}$ grain of matter which was soluble in alcohol, and apparently resinous. He analysed 60768 grains of the same liquid, collected from the vine during the months of July and August. On evaporation he obtained $2\frac{1}{8}$ grains of residuum, composed of $\frac{1}{4}$ grains of carbonate of lime, $\frac{1}{4}$ grain of sulphate of lime, $\frac{1}{2}$ grain of mucilage, and $\frac{1}{4}$ grain of resin. The liquid transpired by the *aster Novæ Angliæ* afforded precisely the same ingredients †.

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* *Veget. Stat.* i. 49.

† *Encyc. Meth. Phys. Veget.* 287.

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Proportion to the liquid absorbed.

3. Sennebier attempted to ascertain the proportion which the liquid transpired bore to the quantity of moisture imbibed by the plant. But it is easy to see that such experiments are liable to too great uncertainties to be depended on. His method was as follows: He plunged the thick end of the branch on which he made the experiment into a bottle of water, while the other end, containing all its leaves, was thrust into a very large glass globe. The apparatus was then exposed to the sunshine. The quantity imbibed was known exactly by the water which disappeared from the bottle, and the quantity transpired was judged of by the liquid which condensed and trickled down the sides of the glass globe. The following Table exhibits the result of his experiments:

Plants.	Imbibed.	Perspired.	Time.
Peach	100 gr	35 gr	
Ditto	210	90	
Ditto	220	120	
Mint	200	90	2 days.
Ditto	575	120	10
Rasp	725	560	2
Ditto	1232	765	2
Peach	710	295	1
Apricot	210	180	1

In some of his experiments no liquid at all was condensed. Hence it is evident that the quantity of matter transpired cannot be deduced from these experiments. The mouth of the glass globe does not seem to have been accurately closed; the air within it communicated with the external air; consequently the quanti-

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ly condensed must have depended entirely upon the state of the external air, the heat, &c.

4. The first great change, then, which takes place upon the sap after it arrives at the leaves, is the evaporation of a great part of it; consequently what remains must be very different in its proportions from the sap. The leaves seem to have particular organs adapted for throwing off part of the sap by transpiration; for the experiments of Guettard *, Duhamel †, and Bonnet ‡, show that it is performed chiefly by the upper surfaces of leaves, and may be nearly stopped altogether by varnishing that surface.

Peculiar organ of transpiration.

The leaves of plants become gradually less and less fit for this transpiration; for Sennebier found that when all other things are equal, the transpiration is much greater in May than in September §. Hence the reason that the leaves are renewed annually. Their organs become gradually unfit for performing their functions, and therefore it is necessary to renew them. Those trees which retain their leaves during the winter, were found by Hales and succeeding physiologists to transpire less than others. It is now well known that these trees also renew their leaves.

Why the leaves fall off.

II. Leaves have also the property of absorbing carbonic acid gas from the atmosphere.

Leaves absorb carbonic acid.

. We are indebted for this very important discovery to the experiments of Dr Priestley. It has been long known that when a candle has been allowed to burn out in any quantity of air, no candle can afterwards be made

* ...m. Par. 1749.
‡ ...te des Feuilles, 1. Mem.

† *Physique des Arbres*, i. 158.
§ *Encyc. Meth. Veget.* 285.

Book IV. to burn in it. In the year 1771, Dr Priestley made a sprig of mint vegetate for ten days in contact with a quantity of such air: after which he found that a candle would burn in it perfectly well *. This experiment he repeated frequently, and found that it was always attended with the same result. According to the opinion at that time universally received, that the burning of candles rendered air impure by communicating phlogiston to it, he concluded from it, that plants, while they vegetate, absorb phlogiston.

Carbonic acid gas was at that time supposed to contain phlogiston. It was natural, therefore, to suppose that it would afford nourishment to plants, since they had the property of absorbing phlogiston from the atmosphere. Dr Percival had published a set of experiments; by which he endeavoured to show that this was actually the case.

These experiments induced Dr Priestley, in 1776, to consider the subject with more attention. But as, in all the experiments which he made, the plants confined in carbonic acid gas very soon died, he concluded that carbonic acid gas was not a food, but a poison to plants †. Mr Henry of Manchester was led in 1784, probably by the contrariety of these results, to examine the subject. His experiments, which were published in the Manchester Transactions ‡, perfectly coincided with those of Dr Percival. For he found that carbonic acid gas, so far from killing plants, constantly promoted their growth and vigour. Meanwhile Mr Sennebier was occupied at Geneva with the same subject;

* *On Air*, iii. 251. † Ibid, i. 100. ‡ Vol. ii. 341.

published the result of his researches in his *es Physico-Chymiques* about the year 1780. His ents showed, in the clearest manner, that acid gas is used by plants as food. The ing was supported by Ingenhousz in his second The experiments of Saussure junior, publish- 797, have at last put the subject beyond the dispute. From a careful comparison of the ex- ts of these philosophers, it will not be difficult discover the various phenomena, and to recon- he seeming contradictions which occur in them, s are as follows:

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ants will not vegetate in an atmosphere of pure acid, nor if their atmosphere contains $\frac{3}{4}$ths of its hat gas. They vegetate in the sun when confi- mospheres containing $\frac{1}{2}$, $\frac{1}{4}$th, or $\frac{1}{8}$th, of that gas, vegetation improves as the quantity of gas di- . When the atmosphere contains only $\frac{1}{12}$th nic acid gas, plants grow in it considerably the sun, than when placed in an atmosphere non air; but when plants are placed in the he presence of carbonic acid always injures etation instead of promoting it *.

Saussure has shown, that plants will not ve- the sun when totally deprived of carbonic acid hey vegetate indeed well enough in air which previously deprived of carbonic acid gas; but quantity of lime was put into the glass vessel ontained them, they no longer continued to

* Saussure, *Recherches Chimiques sur la Vegetation*, p. 30.

Book IV. grow, and the leaves in a few days fell off *. The air, when examined, was found to contain no carbonic acid gas. The reason of this phenomenon is, that plants (as we shall see afterwards) have the power of forming and giving out carbonic acid in certain circumstances; and this quantity is sufficient to continue their vegetation for a certain time. But if this new formed gas be also withdrawn, by quicklime for instance, which absorbs it the instant it appears, the leaves droop, and refuse to perform their functions †. Carbonic acid gas, then, applied to the leaves of plants, is *essential* to vegetation.

4. The direct contrary takes place in the shade. Plants not only continue to vegetate when deprived of all carbonic acid by means of lime; but they flourish more than if it were allowed to remain ‡.

Emit oxygen gas.

5. Dr Priestley, to whom we are indebted for many of the most important facts relative to vegetation, observed, in the year 1778, that plants, in certain circumstances, emitted oxygen gas §; and Ingenhousz very soon after discovered that this gas is emitted by the *leaves* of plants, and only when they are exposed to the bright light of day. His method was to plunge the leaves of different plants into vessels full of water, and then expose them to the sun, as Bonnet, who had observed the same phenomenon, though he had given a wrong explanation of it, had done before him. But

* *Ann. de Chim.* xxiv. 145. 148.

† Braconnot has rendered it probable, that in this experiment it was not the absence of carbonic acid, but the deleterious effects of the lime that killed the plants in Saussure's experiments. *Ann. de Chim.* lxi. 187.

‡ Saussure, *Recherches*, p. 36.

§ *On Air*, iii. 284.

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bles of oxygen gas very soon detached themselves from the leaves, and were collected in an inverted glass vessel *. He observed, too, that it was not a matter of indifference what kind of water was used. If the water, for instance, had been previously boiled, little or no oxygen gas escaped from the leaves; river water afforded but little gas; but pump water was the most productive of all †.

By decomposing carbonic acid.

Sennebier proved, that if the water be previously deprived of all its air by boiling, the leaves do not emit a particle of air; that those kinds of water which yield most air, contain in them the greatest quantity of carbonic acid gas; that leaves do not yield any oxygen when plunged in water totally destitute of carbonic acid gas; that they emit it abundantly when the water, rendered unproductive by boiling, is impregnated with carbonic acid gas; that the quantity of oxygen emitted, and even its purity, is proportional to the quantity of carbonic acid gas which the water contains; that water impregnated with carbonic acid gas gradually loses the property of affording oxygen gas with leaves; and that whenever this happens, all the carbonic acid gas has disappeared; and on adding more carbonic acid gas the property is renewed ‡. These experiments prove, in a most satisfactory manner, that the oxygen gas which the leaves of plants emit depends upon the presence of carbonic acid gas; that the leaves absorb carbonic acid gas, decompose it, give out the oxygen, and retain the carbon. They have been lately confirmed by the expe-

* Ingenhousz *on Veget.* i. 15, &c. † Ibid. 83.
‡ *Encyc. Method. Physiol. Veget.* 181.

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riments of Dr Woodhouse. To this gentleman likewise we are indebted for a very full set of experiments on the quantity of gas produced by exposing different plants in water to sunshine for given times *.

The decomposition performed by the parenchyma.

6. Sennebier has ascertained, that the decomposition of the carbonic acid takes place in the parenchyma. He found that the epidermis of a leaf would, when separated, give out no air, neither would the nerves in the same circumstances; but upon trying the parenchyma, thus separated from its epidermis and part of its nerves, it continued to give out oxygen as before †.

That the decomposition is performed by peculiar organs, is evident from an experiment of Ingenhousz. Leaves cut into small pieces continued to give out oxygen as before; but leaves pounded in a mortar lost the property entirely. In the first state, the peculiar structure remained; in the other, it was destroyed. Certain experiments of Count Rumford, indeed, may seem incompatible with this conclusion; and they will naturally occur to the reader as an objection. He found that dried leaves, black poplar, fibres of raw silk, and even glass, when plunged into water, gave out oxygen gas by the light of the sun; but when Sennebier repeated these experiments, they did not succeed ‡. It was probably the air contained in the water which separated in the Count's experiments §.

* See Nicholson's *Jour.* ii. 154. and *Ann. de Chim.* xlii. 200.

† *Encyc. Method. Physiol. Veget.* 180.

‡ *Ann. de Chim.* i. 115.

§ Dr Woodhouse tried the experiments with filaments of asbestus, baked horse hair, cotton, panicles of rhus cotinus, cotton of asclepias syriaca, hairy plumes of clematis crispa, spikes of panicum glaucum, char-

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Carbonic acid absorbed varies in different plants.

om the experiments of Saussure, we learn that ntity of carbonic acid thus absorbed and decom- raries greatly in different plants, even when n the same circumstances. The *lythrum sali-* as found to absorb seven or eight times its bulk gas in a day; while the *cactus opuntia*, and shy-leaved plants, did not absorb above a fifth quantity. The portion absorbed, according to e, depends upon the surface of the plant; and e thin leaved plants must absorb more than at have fleshy leaves *.

The whole oxygen not emitted.

does not appear that the whole of the oxygen d in the carbonic acid absorbed is emitted again lant. A considerable portion of it seems to be . This, at least, is the result which follows et of experiments made by Saussure on pur- scertain the point. He mixed carbonic acid nmon air, in such a proportion that it occupied redths of the mass. Jars, standing over mer- vered with a thin film of water), were filled with ture; and plants of *vinca minor*, growing in a essel filled with water, were introduced into the hese plants, thus placed, were exposed for six ve days to the sun, from five in the morning to while the temperature of the air was 70°; du- which time they vegetated with great vigour. lk of the air in the jar was not sensibly altered. onic acid could be detected in it. The pro-

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der; each of these, he affirms, yielded in water a little oxygen ss pure than the leaves of plants. Nicholson's *Jour.* ii. 158.

erches Chimiques, p. 56.

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portion of oxygen was $24\frac{1}{2}$ *per cent.* The follow Table exhibits the proportion of the constituents of air, in French cubic inches, when put into the jar, after the plants had vegetated in it six days*:

	When put in.	When taken out.
Azote	211·92	218·95
Oxygen	56·33	71·05
Carbonic acid	21·75	0·00
	290·00	290·00

Some azote emitted.

Thus the whole 21·75 inches of carbonic acid w absorbed; but the oxygen emitted was only 14· inches, whereas the whole oxygen in the carbonic a would have amounted to 21·75 inches. The dif ence, amounting to about seven inches, was made by a quantity of azote, which had been given out the plants along with the oxygen. The followi Table exhibits the result of similar experiments, ma by this philosopher, on other plants. All the nu bers denote cubic inches.

* Recherches, p. 40.

Plants.	Bulk of plants.	Air in jar.	Carbonic acid, *per cent.* in ditto.	Duration of experiment.	Carbonic acid *per cent.* in residuary air.	Oxygen *per cent.* in do.	Carbonic acid absorbed.	Gas emitted. Oxygen.	Gas emitted. Azote.	Diminution of bulk of residuary gas.
Mentha aquatica	0·5	328	7·5	Days. 10	2·5	23·5	15·6	11·26	4·34	0
Lythrum salicaria	0·14	75	10	7	0	27·25	7·5	6·13	1·1	0·5
Pinus Genevensis	0·5	280	7	18	1·5	24·5	15·5	12·5	1	2
Cactus opuntia	1·1	155	10	8	4	24	9·3	6·4	2·9	0

us it appears that plants, when exposed to the sorb carbonic acid, decompose it, and throw the greatest part of the oxygen of this gas would seem) with a little *azote**. It is ex-

e that Saussure ascertained merely that the new portion

Book IV. tremely probable that plants, by this process, acquire the greatest part of the carbonaceous matter which they contain; for if we compare the quantity of carbon contained in plants vegetating in the dark, where this process does not go on, with the quantity which those plants contain which vegetate in the usual manner, we shall perceive a very conspicuous difference. Chaptal found that a byssus, which was vegetating in the dark, contained only $\frac{1}{10}$th of its weight of carbonaceous matter; but the same plant, after being made to vegetate in the light for 30 days, contained $\frac{1}{3}$th of its weight of carbonaceous matter *. Hassenfratz ascertained, that plants growing in the dark contain much more water, and much less carbon and hydrogen, than plants growing in the light. Sennebier analysed both with the same result. Plants growing in the dark yielded less hydrogen gas and oil: their resinous matter was to that of plants growing in the light as 2 to 5·5, and their moisture as 13 to 6; they contained even one-half less of fixed matters.

The quantity of carbonic acid thus absorbed is considerable. In Saussure's experiments, the plants absorbed daily more than their own bulk of this gas: But when they grow in the open air, where the quantity of carbonic acid is much less considerable, not exceeding $\frac{1}{100}$th part, the proportion absorbed is no doubt less.

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of gas, to which he has given the name of azote, did not diminish with oxygen, and did not render lime-water turbid. Many other gases possess these properties. It might have been some inflammable gas. Hydrogen would have detonated; but some of the compound inflammable gases would not, when diluted so largely with common air.

* *Mem. Par.* 1786.

Plants emit no oxygen in the dark.

10. Ingenhousz found that plants emit no oxygen when made to vegetate in the dark, and that in these circumstances they rather injure air than improve it. Now, as the emission of oxygen has been found to depend upon the absorption of carbonic acid, it is probable that this acid is absorbed only in the light. Saussure indeed has endeavoured to prove, that plants, even in the dark, absorb and decompose carbonic acid; but the quantity, if any, must be so extremely small, that it cannot well be appreciated.

Green colour produced by light.

III. The green colour of plants has been shown, by Sennebier, to depend upon the absorption of carbonic acid. It appears only when plants vegetate in the light: for when they vegetate in the dark they are white; and when exposed to the light they acquire a green colour in a very short time, in whatsoever situation they are placed, even though plunged in water, provided always that oxygen be present; for Mr Gough has shown, that light without oxygen has not the power of producing the green colour *.

Sennebier has observed, that when plants are made to vegetate in the dark, their etiolation is much diminished by mixing a little hydrogen gas with the air that surrounds them †. Ingenhousz had already remarked, that when a little hydrogen gas is added to the air in which plants vegetate, even in the light, it renders their verdure deeper ‡: and he seems to think also, that he has proved by experiments, that plants absorb hydrogen gas in these circumstances §. Mr Humboldt has

* *Man. Mem.* iv. 501.

† *Encyc. Meth. Physiol. Veget.* 75.

‡ *Ann. de Chim.* iii. 57.

§ Ibid. 61.

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observed that the *poa annua* and *compressa*, *plantago lanceolata*, *trifolium arvense*, *cheiranthus cheiri*, *lichen verticillatus*, and several other plants which grow in the galleries of mines, retain their green colour even in the dark, and that in these cases the air around them contains a quantity of hydrogen gas. This philosopher concludes, from his observations, that the white colour of etiolated plants is occasioned by their retaining an unusual proportion of oxygen, and that this is prevented by surrounding them with hyrogen gas. This may perhaps be true in certain cases; but the experiments of Mr Gough, mentioned above, are sufficient to prove that the retention of oxygen is not the only difference between green and etiolated plants *.

Plants supposed to decompose water.

The green colouring matter of plants has been shown by Rouelle to be of a resinous nature. From this, and from the circumstance of its being formed only in the light, Berthollet has inferred that the leaves of plants have the property of decomposing water as well as carbonic acid when exposed to the light of the sun. The oxygen emitted, according to him, is derived partly from the decomposed carbonic acid and partly from the water, while the carbon and hydrogen enter into the composition of the inflammable parts of the plant. This ingenious theory, though sufficiently probable, is not susceptible of direct proof. From the experiments of Saussure, we learn that when plants are made to vegetate in pure water, in atmospheres destitute of carbonic acid gas, the quantity of their fixed matter does

* Plants of a white colour, from vegetating in [illegible] *etiolated*, from a French word which signifies a [illegible] *star light*.

not increase; but when their atmospheres contain this acid gas, the increase of weight which they receive is considerably greater than can be accounted for by the carbon and oxygen derived from the carbonic acid absorbed *. Hence it is clear, that a portion of the water must enter into their composition. It is more likely that the elements of this portion arrange themselves in a different way, than that they still continue in the state of water. These facts certainly strengthen the hypothesis of Berthollet. Indeed, if we consider the great quantity of hydrogen contained in plants, it is difficult to conceive how they should obtain it, provided the water which they absorb does not contribute to furnish it.

Plants absorb oxygen,

IV. Plants will not vegetate unless atmospheric air or oxygen gas have access to their leaves. This was rendered probable by those philosophers who, about the end of the 17th century, turned their attention particularly towards the physical properties of the air; but Dr Ingenhousz was perhaps the first of the modern chemists who put it beyond doubt. He found that carbonic acid gas, azotic, and hydrogen gas, destroyed plants altogether, unless they were mixed with atmospheric air or oxygen gas. He found also, that plants grew very well in oxygen gas and in atmospheric air †. From these experiments, it was pretty clear that the leaves of plants absorb oxygen; and the whole series of chemical experiments on plants led to the supposition that this absorption was confined to the night. The subject has lately been very fully investigated by Saus-

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* ...17.

† Ingenhousz, ii. passim.

Book IV. sure, who has not only confirmed these suppositions by decisive experiments, but added many new facts not previously suspected *.

1. The greater number of plants refuse to vegetate when confined in azotic gas. Those only continue to live which are abundantly supplied with green parts, as the *cactus opuntia*, &c. When plants continue to vegetate in azote, it is because they give out a portion of oxygen during the day; the absorption of which during the night preserves them †.

2. When the leaves of plants are put in contact with common air during the night, they diminish the bulk of their atmosphere by absorbing oxygen. Some plants change, at the same time, a portion of the oxygen into carbonic acid, while others form no perceptible quantity of this last gas. The leaves, for example, of the *cactus opuntia, crassula cotyledon, sempervivum tectorum, agave Americana*, and *stapelia variegata*, simply absorb oxygen; while the leaves of the *quercus robur, sedum reflexum, æsculus hyppocastanum*, and *robinia pseudo-acacia*, absorb oxygen, and form a portion of carbonic acid, inferior in quantity to the oxygen which has disappeared ‡.

3. This inspiration of oxygen takes place only when the leaves retain their organized form. If this be destroyed, by reducing them to a paste for example, all absorption of oxygen is prevented, though a portion of it is even then converted into carbonic acid by the action of the carbonaceous matter present §.

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* *Recherches*, p. 60. † Ibid. p. 197. ‡ Saussure, Ibid. p. 61.
§ Ibid. p. 74.

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4. The oxygen thus inspired by the leaves of plants, not separated from them again by putting them into e exhausted receiver of the air pump. By that eans, indeed, they yield a little air, but always much s than the oxygen absorbed; and this air is precisely the same nature with the atmosphere in which they re confined. Neither is the oxygen extricated by posing the leaves to the greatest heat which they are pable of bearing without being destroyed *.

And convert it into carbonic acid.

5. There is reason to believe that the oxyen gas us absorbed by plants is converted into carbonic acid thin the plant, and that it is only after the plant is *urated* with this acid (if the expression may be pertted), that the surrounding oxygen is partly convertinto carbonic acid, by combining with the carbonaous matter of the plant. When the leaves are expo- to the light, this carbonic acid is decomposed, and antity of oxygen thrown out, usually greater than t was inspired. But the oxygen given out in the (when plants grow in atmospheres destitute of onic acid) is always proportional to the oxygen ind during the night; being always greatest when lant has absorbed the greatest quantity of oxygen.

Differ in the quantity absorbed.

Plants differ very much from each other in the ty of oxygen which their leaves absorb during ht. Fleshy-leaved plants absorb the least oxyrobably because they emit no carbonic acid gas. they can vegetate in high situations where the here is rarefied. Next in order come the everees, which, though they absorb more oxygen

* *Recherches*, p. 69.

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than the fleshy-leaved plants, yet require much less than those trees which lose their leaves during winter. Those plants which flourish in marshy ground likewise absorb but little oxygen. The following Tables exhibit the result of Saussure's experiments on this point. The first column contains the names of the plants whose leaves were employed; the second the month in which the experiments were made; and the third the bulk of oxygen absorbed, supposing the bulk of the leaves used in each experiment to be always 1·00 *.

Tables of the proportion absorbed.

I. *Leaves of Evergreen Trees.*

Leaves of	Time.	Oxygen absorbed.
Ilex aquifolium	September	0·86
Buxus semper virens	Ditto	1·46
Prunus laurocerasus	May	3·20
Ditto	September	1·36
Viburnum tinus	September	2·23
Hedera helix	September	1
Vinca minor	June	1·5
Ditto	September	0·93
Pinus abies	September	3
Beupleurum fruticosum	May	4
Juniperus sabina	June	2·6
Juniperus communis	June	2·4

* *Recherches*, p. 99.

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II. *Leaves of Trees which lose their leaves in Winter.*

Leaves of	Time.	Oxygen absorbed.
Fagus sylvatica	August	8
Carpinus betulus	May	5
Ditto	September	6
Quercus robur	May	5·5
Ditto	September	5·5
Æsculus hyppocastan.	September	4·8
Populus alba	May	6·2
Ditto	September	4·36
Prunus Armeniaca	September	8
Amygdalus Persica	June	6·6
Ditto	September	4·2
Juglans regia	May	6·6
Ditto	September	4·4
Platanus occidentalis	September	3
Robinia pseudo-acacia	May	5
Ditto	September	6·7
Syringa vulgaris	May	3·36
Ditto	September	2·2
Fraxinus excelsior	May	4·32
Ditto	September	3·71
Pyrus	May	5·2
Ditto	September	3·4
Rosa centifolia	June	5·4
Fagus castanea	July	5·6

III. *Leaves of Herbaceous Plants, not Aquatic.*

Leaves of	Time.	Oxygen absorbed.
Solanum tuberosum	September	2·5
Brasica oleracea	Ditto, young leaves	2·4

Leaves of	Time.	Oxygen absorbed.
Brassica oleracea	Sept. old leaves	2
Urtica urens	September	2
Mercurialis annua	Sept. in flower	2·33
Daucus carota	September, ditto	1·9
Vicia faba	Before flowering	3·7
Ditto	In flower	2
Ditto	After ditto	1·6
Lilium candidum	May, in flower	0·66
Ditto	Sept. after ditto	0·5
Tropæolum majus	Sept. in flower	3
Digitalis ambigua	July	2
Brassica rapa	Sept. in flower	1·25
Avena sativa	June, before ditto	2·7
Triticum æstivum	May, before ditto	5·0
Pisum sativum	May, in flower	3·72
Ruta graveolens	August	2

IV. *Leaves of Aquatic Plants.*

Leaves of	Time.	Oxygen absorbed.
Alisma plantago	August	0·7
Inula dysenterica	September	1·6
Epilobium molle	Sept. in flower	1·9
Sisymbrium nasturtium	September	1·6
Polygonum Persicaria	Sept. in flower	2
Veronica beccabunga	September	1·7
Ranunculus reptans	September	1·5
Lythrum salicaria	May, before flower	2·3
Caltha palustris	May	1
Carex acuta	May	2·25

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V. *Leaves of the Fleshy Plants.*

Leaves of	Time.	Oxygen absorbed.
Cactus opuntia	August	1
Agave Americana	August	0·8
Sempervivum tectorum	July	1
Sedum globosum	September	1·5
Saxifraga cotyledon	September	0·6
Sedum reflexum	June	1·7
Stapelia variegata	July	0·63
Mesembryanthemum deltoides	July	1·7

7. It is not improbable, that by the absorption of oxygen, and the formation of carbonic acid, a portion of heat may be evolved, as Saussure supposes; though the quantity must be too small to be appreciated. It appears that in certain cases a very considerable degree of heat is produced by vegetables; though it has not yet been ascertained whether the appearance of it is connected with the absorption of oxygen. A very extraordinary instance of this is related by Bory de St Vincent on the authority of Hubert. The stamina of the *arum cardifolium*, at the moment of bursting, produced so great a heat, that twelve of them placed round the bulb of a thermometer raised it from 79° to 143°. The experiment was repeated a great number of times with similar results *.

Heat may be evolved.

8. It appears, from the experiments of Saussure, that the roots absorb oxygen as well as the leaves, and that

Roots absorb oxygen.

* *Jour. de Phys.* lix. 281.

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they transmit the carbonic acid formed to the leaves to be decomposed. The branches likewise absorb it. Flowers do not expand without its presence.

Thus it appears that during the night plants absorb oxygen; that they form with it carbonic acid; that a portion of this gas is sometimes emitted, together with a little azote; but that the greatest part is retained and decomposed by the leaves during the day. Plants will not live without this nightly inspiration, even though supplied with carbonic acid, provided the oxygen formed by them during the day be constantly withdrawn at the approach of night.

Leaves absorb water.

V. The leaves of plants absorb water as well as oxygen from the air. This had been suspected in all ages: the great effect which dew, slight showers, and even wetting the leaves of plants, have in recruiting their strength, and making them vegetate with vigour, are so many proofs that the leaves imbibe moisture from the atmosphere. Hales rendered this still more probable, by observing that plants increase considerably in weight when the atmosphere is moist; and Mr Bonnet put the matter beyond doubt in his *Researches concerning the Use of the Leaves*. He showed that leaves continue to live for weeks when one of their surfaces is applied to water; and that they not only vegetate themselves, but even imbibe enough of water to support the vegetation of a whole branch, and the leaves belonging to it. He discovered also, that the two surfaces of leaves differ very considerably in their power of imbibing moisture; that in trees and shrubs the under surface possesses almost the whole of the property, while the contrary holds in many of the other plants; the kidney bean for instance.

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These facts prove not only that the leaves of plants have the power of absorbing moisture, but also that the absorption is performed by very different organs from those which emit moisture; for these organs lie on different sides of the leaf. If we consider that it is only during the night that the leaves of plants are moistened with dew, we can scarcely avoid concluding, that, except in particular cases, it is during the night that plants imbibe almost all the moisture which they do imbibe.

Thus we have seen that the leaves of plants perform very different operations at different times. During the day they are giving out moisture, absorbing carbonic acid gas, and emitting oxygen gas; during the night, on the contrary, they are absorbing moisture, giving out carbonic acid gas, and absorbing oxygen gas.

Sap converted into nutritive juices by these processes.

By these processes, and perhaps also by others which have not yet been detected, the sap of plants is new modelled, and brought to the state which is adapted for the nourishment of the plant. To describe in what manner these changes take place is impossible; because we neither know precisely the substance into which the sap has been converted by the operations performed during the day, nor the new substances formed by the operations of the night. We have reason, however, to conclude, that during the day the carbon of the sap is increased, and that during the night the hydrogen and oxygen are increased; but the precise new substances formed are unknown to us. Nor let any one suppose that the increase of the hydrogen and of the oxygen of the sap is the same thing as the addition of a quantity

of water. In water, oxygen and hydrogen are already combined together in a certain proportion; and this combination must be broken before these elementary bodies can enter into those triple compounds with carbon, of which a great part of the vegetable products consist. We have not the smallest conception of the manner in which these triple combinations are formed, and as little of the manner in which the bodies which compose vegetable substances are combined together. The combination, may, for any thing we know to the contrary, be very complicated: though it consists only of three ingredients; and analogy leads us to suppose that it actually is very complicated: for in chemistry it may be considered as a truth, to which at present few or no exceptions are known, that bodies are decomposed with a facility inversely as the simplicity of their composition; that is to say, that those bodies which consist of the fewest ingredients are most difficultly decomposed, and that those which are formed of many ingredients are decomposed with the greatest facility.

Neither let any one suppose that the absorption of carbonic acid gas during the day is balanced by the quantity emitted during the night; and that therefore there is no increase of carbon: for Ingenhousz and Saussure have shown that the quantity of oxygen gas emitted during the day is much greater than the carbonic acid gas emitted during the night; and that in favourable circumstances, the quantity of oxygen gas in the air surrounding plants is increased, and the carbonic acid gas diminished; so much so, that both Dr Priestley and Dr Ingenhousz found, that air which had been spoiled by a lighted candle, or by animals, was rendered as good as ever by plants. Now we know that com-

bustion and respiration diminish the oxygen gas, and add carbonic acid gas to air; therefore vegetation, which restores the purity of air altered by these processes, must increase the oxygen, and diminish the carbonic acid gas of that air; consequently the quantity of carbonic acid gas absorbed by plants during the day is greater than the quantity emitted by them during the night; and of course the carbon of the sap is increased in the leaves. Chap. III.

It is true, that when plants are made to vegetate for a number of days in a given quantity of air, its ingredients are not found to be altered. Thus Hassenfratz ascertained that the air, in which young chesnuts vegetated for a number of days together, was not altered in its properties, whether the chesnuts were vegetating in water or in earth *; and Saussure junior proved that peas growing for ten days in water did not alter the surrounding air †. But this is precisely what ought to be the case, and what must take place, provided the conclusions which I have drawn be just. For if plants only emit oxygen gas by absorbing and decomposing carbonic acid gas, it is evident, that unless carbonic acid gas be present, they can emit no oxygen gas; and whenever they have decomposed all the carbonic acid gas contained in a given quantity of air, we have no longer any reason to look for their emitting any more oxygen gas; and if the quantity of carbonic acid gas emitted during the night be smaller than that absorbed during the day, it is evident that during the day the plant will constantly decompose all the acid which had been form-

* *Ann. de Chim.* xiii. 325.

† Ibid. xxiv. 139.

Book IV. ed during the night. By these processes the mutual changes of day and night compensate each other; and they are prevented from more than compensating each other by the forced state of the plant. It is probable, that when only part of a plant is made to vegetate in this forced state, some *carburated sap* (if I may be allowed the expression) is supplied by the rest of the plant; and that therefore the quantity of carbonic acid gas emitted during the night may bear a nearer proportion to that emitted in a state of nature than that of the absorption of fixed air can possibly do. And probably, even when the whole plant is thus confined, the nightly process goes on for a certain time at the expense of the carbon already in the sap; for Hassenfratz found, that in these cases the quantity of carbon in the plant, after it had vegetated for some time in the dark, was less than it had been when it began to vegetate*. This is the reason that plants growing in the dark, when confined, absorb all the oxygen gas, and emit carbonic acid gas: and whenever this has happened, they die; because then neither the daily nor nightly processes can go on.

SECT. V.

OF THE PECULIAR JUICES OF PLANTS.

By these changes which go on in the leaves, the nature of the sap is altogether changed. It is now con-

* *Ann. de Chim.* xiii. 188.

nto what is called the *peculiar juice*, or *true sap*, fit for being assimilated to the different parts plant, and for being employed in the formation secretions which are necessary for the purposes egetable economy.

Leaves the digesting organs of plants.

leaves, therefore, may be considered as the di- organs of plants, and as equivalent in some mea- the stomach and lungs of animals. The leaves ently are not mere ornaments; they are the portant parts of the plant. Accordingly we find, enever we strip a plant of its leaves, we strip it of its vegetating powers till new leaves are It is well known that when the leaves of re destroyed by insects they vegetate no longer, t their fruit never makes any farther progress in g, but decays and dries up. Even in germina- progress is made in the growth of the stem till l-leaves appear. As much food indeed is laid e cotyledons as advances the plant to a certain the root is prepared, and made ready to perform tions; but the sap which it imbibes must be ried to the seed-leaves, and digested there, be- be proper for forming the plumula into a stem. ngly if the seed-leaves are cut off, the plant re- vegetate.

How they are produced.

ll be very natural to ask, If this be true, how e leaves themselves to be produced? I had en- red to render it probable, that food for the pur- nourishing and developing them was laid up in s themselves; but the late experiments of Mr formerly detailed, have shown that the alburn the part of the tree in which this food is depo- After the plant has developed all the parts

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which are to appear during the summer, and after the buds are fabricated and rolled up, the leaves still continue to manufacture new food, and to send it to the alburnum. Here it is deposited, and employed next spring in feeding and developing those organs of plants which are absolutely necessary for enabling them to perform the functions of vegetation. From this important fact, Mr Knight has drawn a number of curious consequences, of great importance to the practical gardener and farmer.

This deposition of food for the future supply of the plant, explains to us why the branch of a vine, if it be introduced into a hot-house during the winter, puts forth leaves and vegetates with vigour, while every other part of the plant gives no signs of life. It explains to us also why the sap flows out of trees very readily in spring before the leaves appear, but after that the bleeding ceases altogether. It is evident that there can be scarcely any circulation of sap before the leaves appear; for as there is no outlet, when the vessels are once full they can admit no more. It appears, however, from the bleeding, that the roots are capable of imbibing, and the vessels of circulating, the sap with vigour. Accordingly, whenever there is an outlet, they perform their functions as usual, and the tree bleeds; that is, they send up a quantity of sap to be digested as usual: but as there are no digesting organs, it flows out, because the sap that flows out would not have been imbibed at all, had it not been for the artificial opening. But when the digestive organs appear, the tree will not bleed; because these organs require all the sap, and it is constantly flowing to them.

If a tree be deprived of its leaves, new leaves make

Chap. III.

eir appearance, because they are already prepared for at purpose. But what would be the consequence if a ee were deprived of its leaves and of all its buds for e years back? That plants do not vegetate without ives is evident from an experiment of Duhamel. He ipt the bark off a tree in ringlets, so as to leave five six rings of it at some distance from each other, with bark in the intervals. Some of these rings had buds d leaves; these increased considerably in size; but e ring which had none of these remained for years altered. Mr Knight found that a shoot of the vine, hen deprived of its leaves died altogether *.

Absolutely necessary.

The *succus proprius*, or *peculiar juice* of plants may considered as analogous to the blood of animals. It the food altered by digestion, and rendered fit for be- assimilated and converted into a part of the plant elf by the subsequent processes of vegetation. That flows from the leaves of the plant towards the roots ears from this circumstance, that when we make an sion into a plant, into whatever position we put it, h more of the *succus proprius* flows from that side e wound which is next the leaves and branches from the other side: and this happens even though aves and branches be held undermost †. When a re is tied about a plant, a swelling appears above t below the ligature.

Form the peculiar juice,

Which flows from the leaves

vessels containing the peculiar juice have been by Mr Knight from the leaves into the cortical of the inner bark ‡. Hedwig, who has examined sels of plants with very great care, seems to con-

In vessels.

l. Trans. 1801, p. 338. † Bell, *Manch. Mem.* ii. 402.
. Trans. 1801, p. 337.

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sider them as of the same structure with the tracheæ; but Mr Knight is of a different opinion. It appears evidently from the experiments of this last gentleman, that they communicate with no part of the plant which is situated at a greater distance from the root than the leaf from which they themselves originate. For when two circular incisions are made through the bark of a branch above and below a leaf, and at some distance from it, only that part of the portion confined between the two incisions which is situated below the leaf increases in size. From the late experiments of Mr Knight, there is reason to believe that these vessels are much better calculated to carry the true sap from the leaves towards the roots, than in the contrary direction. By passing the slender shoots of a vine through the earth of a garden-pot, he made them send out roots. The shoots were then cut off from the parent tree, leaving an equal portion on each side of this new root. Each of these portions was turned up at a similar angle, and had a bud at a little distance from the cut-off extremity. Here were two stems growing from one root. But the one was obviously inverted, while the other was in its natural position. In the first, the wood between the bud and the cut-off extremity increased in size; but in the other it did not: indicating a disposition in the true sap to move in its original direction from the leaves to the root. In like manner, when shoots of gooseberry and currant bushes were planted inverted, the upper part always decayed*. These experiments are favourable to the opinion, that these vessels are furnished with valves.

* Nicholson's *Jour.* x. 289.

all communication between the leaves and cut off, by removing a portion of the bark all he tree, it appears, from the experiments of that the alburnous vessels acquire the property nitting a portion of the true sap to the roots, maintain the powers of vegetating; but the is greatly diminished. The surplus appears odged in the alburnum, which thus becomes and if the plant be allowed to vegetate, this expended next season upon the upper part of t. Thus the quantity of blossom on the branch ple tree is greatly increased by removing a sects bark the season before the blossom is to ap- Chap. III.

rue sap is easily known by its colour and its ice. In some plants it is green, in some red, milky. It cannot be doubted that its motion essels is performed in the same way as that of

Its properties.

had any method of obtaining this peculiar juice e of purity, the analysis of it would throw a al of light upon vegetation; but this is scarce, as we cannot extract it without dividing at the ne the vessels which contain the sap. In many owever, the peculiar juice may be known by its and then its analysis may be performed with an h towards accuracy. The facts respecting its ents, hitherto ascertained by chemists, have, as am acquainted with them, been detailed in the ng Chapter. These experiments prove, as might

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it on the *Inverted Action of the Alburnous Vessels of Trees*. *Phil.* 06.

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have been expected, that the peculiar juices differ very considerably from each other, and that every plant has a juice peculiar to itself. Hence it follows, that the processes which go on in the leaves of plants must differ at least in degree, and that we have no right to transfer the conclusions deduced from experiments on one species of plants to those of another species. It is even probable, that the processes in different plants are not the same in kind; for it is not reasonable to suppose that the phenomena of vegetation in an agaric or a boletus are precisely the same as those which take place in trees and in larger vegetables, on which alone experiments have hitherto been made.

The true sap is conveyed to every part of the plant; and all the substances which we find in plants, and even the organs themselves by which they perform their functions, are formed from it. But the thickest veil covers the whole of these processes; and so far have philosophers hitherto been from removing this veil, that they have not even been able to approach it. All these operations indeed, are evidently chemical decompositions and combinations; but we neither know what these decompositions and combinations are, nor the instruments in which they take place, nor the agents by which they are regulated.

SECT. VI.

OF THE DECAY OF PLANTS.

Plants decay and die.

, as far as I am acquainted with them, are the es produced by vegetation. But plants do not ue to vegetate for ever; sooner or later they de- d wither, and rot, and are totally decomposed. change indeed does not happen to all plants at the the same time. Some live only for a single sea- r even for a shorter period; others live two sea- thers three, others a hundred or more; and there me plants which continue to vegetate for a thou- ears: but sooner or later they all cease to live; n those very chemical and mechanical powers had promoted vegetation combine to destroy the of the plant. Now, What is the cause of this ? Why do plants die?

question can only be answered by examining e care what it is which constitutes the *life* of or it is evident, that if we can discover what ich constitutes the life of a plant, it cannot be discover whatever constitutes its death.

Phenomena of vegetable life

e phenomena of vegetable life are in general As long as a plant continues to vegetate, t it lives; when it ceases to vegetate, we at it is dead.

of vegetables, however, is not so intimately th the phenomena of vegetation that they parated. Many seeds may be kept for giving any symptom of vegetation; yet

they vegetate when put into the earth, we say tha they possess life; and if we would speak accurately, w must say also that they possessed life even before they were put into the earth: for it would be absurd to suppose that the seed *obtained* life merely by being put into the earth. In like manner many plants decay, and give no symptoms of vegetation during winter; yet if they vegetate when the mild temperature of spring affects them, we consider them as having lived all winter. The life of plants, then, and the phenomena of vegetation, are not precisely the same thing; for the one may be separated from the other, and we can even suppose the one to exist without the other. Nay, what is more, we can, in many cases, *decide*, without hesitation, that a vegetable is not dead, even when no vegetation appears; and the proof which we have for its life is, that it *remains unaltered*; for we know that when a vegetable is dead, it soon changes its appearance, and falls into decay.

Thus it appears that the *life* of a vegetable consists in two things: 1. In remaining unaltered, when circumstances are unfavourable to vegetation; 2. In exhibiting the phenomena of vegetation when circumstances are favourable. When neither of these two things happens, we may say that a vegetable is dead.

The phenomena of vegetation have been enumerated above. They consist in the formation or expansion of the organs of the plant, in the taking in of nourishment, in carrying it to the leaves, in digesting it, in distributing it through the plant, in augmenting the bulk of the plant, in repairing decayed parts, in forming new organs when they are necessary, in producing seeds capable of being converted into plants similar to the pa-

rent. The *cause* of these phenomena, whatever it may be, is the *cause* also of *vegetable life*, and may be distinguished by the name of the *vegetative principle*. But an inquiry into the nature of this principle belongs to the science of *physiology*, and would be foreign to the nature of this Work.

Owing to a vegetative principle.

The death of plants, if we can judge from the phenomena, is owing to the organs becoming at last altogether unfit for performing their functions, and incapable of being repaired by any of the powers which the vegetative principle possesses. The changes which vegetable substances undergo after death come now to be examined. They shall form the subject of the ensuing Chapter.

Death of plants.

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CHAP. IV.

OF THE DECOMPOSITION OF VEGETABLE SUBSTANCES.

Difference between minerals and living matter.

THE most striking distinction between the substances belonging to the mineral kingdom and those which make a part of animals or vegetables, is the following: Mineral bodies show little or no tendency to change their nature; and when left to themselves, undergo no spontaneous decompositions: whereas animal and vegetable substances are continually altering; and when left to themselves in favourable circumstances, always run through a regular set of decompositions. I propose in this Chapter to treat of the spontaneous decompositions of vegetable bodies; those of animal bodies belong to the next Book.

Vegetable substances go through a series of changes.

We have seen in the last Chapter, that during vegetation the constituents of plants are continually going through a regular set of changes, losing the properties of one substance, and assuming those of another. Thus a substance which in the young plant has the properties of mucilage, assumes in the old the properties of starch; what in green fruit is an acid, in ripe fruit becomes

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gar. Vegetable principles, then, are not fixed or sta-
nary in the living plant; they are gradually running
to one another. But this tendency to change, or ra-
er this continual decomposition in consequence of the
utual reaction of the different simple substances of
hich the vegetable principles are composed, is by no
eans confined to the living state. It goes on with
ual or with greater energy in favourable circum-
nces in vegetable matter after it has been completely
parated from the living plants. It has been observed
at this tendency to spontaneous decomposition is
ually greater in animal than in vegetable bodies; and
at those vegetable bodies, in which the tendency is
eatest, bear the closest resemblance to animal matter.
ence the common chemical phrase, that such sub-
nces are *more animalized*. This is the case with *glu-
n* in particular, which undergoes spontaneous decom-
sition more rapidly than most other vegetable bodies.

These spontaneous alterations.

During the spontaneous decomposition which vege-
ble substances undergoes, it is obvious that the simple
bstances of which they are composed must unite to-
ether in a different manner from that in which they
ere formerly united, and form a new set of compounds
hich did not formerly exist. Now it has been ob-
erved that the specific gravity of these new compounds
s almost always less than that of the old body. Some
f them usually fly off in the state of gas or vapour.
Hence the odour that vegetable bodies emit during the
whole time that they are running through the series of
heir changes. When the odour is very offensive or
oxious, the spontaneous decomposition is called *putre-
action*; but when the odour is not offensive, or when

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Called *fermentation.*

any of the new compounds formed is applied to useful purposes, the spontaneous decomposition is called *fermentation.* This word was first introduced into chemistry by Van Helmont *. It is supposed by some to have originated from the intestine motion which is always perceptible while vegetable substances are fermenting; while by others it is derived from the heat which in these cases is always generated. The term *fermentation* is now very often applied to all the spontaneous changes which vegetable bodies undergo without regard to the products. It therefore, in that sense, includes *putrefaction;* and certainly there is no impropriety in thus extending the term so as to make it comprehend every case of spontaneous decomposition. By fermentation, then, is now meant all the spontaneous changes which take place in vegetable substances after they are separated from the living plant.

All the phenomena of fermentation lay for many years concealed in the completest darkness, and no chemist was bold enough to hazard even an attempt to explain them. They were employed, however, and without hesitation too, in the explanation of other phenomena; as if giving to one process the name of another, of which we are equally ignorant, could, in reality, add any thing to our knowledge. The darkness which enveloped these phenomena has lately begun to disperse; but they are still surrounded with a very thick mist; and we must be much better acquainted with the composition of vegetable substances, and the mutual affini-

* Stahl's *Fundament. Chem.* i. 124.

their ingredients, than we are at present, before explain them in a satisfactory manner.

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nentation never takes place unless vegetable sub- contain a certain portion of water, and unless re exposed to a temperature at least above the g point. When dry or freezing, many of them le long without alteration. Hence we have an s method of preventing fermentation.

Tendency differs in different bodies.

e take a view of all the vegetable principles de- l in the first Chapter of this Book, we shall find ey differ much from one another in their tendency into fermentation. Gum, sarcocol, starch, indigo, esins, camphor, caoutchouc, gum resins, wood, ber, though mixed with water, and placed in the avourable temperature, show scarcely any tenden- change their nature. Oils absorb oxygen from nosphere but too slowly to produce any intestine l. Tannin, some of the acids, and extractive, adually decomposed; the surface of the liquid be- mouldy, and an insipid sediment falls to the bot- and when the process has once begun, it goes on reater rapidity. Albumen and fibrin putrefy very y, but the products have not been ascertained; gradually changes into a kind of cheese.

Greatest in compounds.

it is when several of the vegetable principles ixed together, that the fermentation is most per- le, and the change most remarkable. Thus when is added to a solution of sugar in water, the li- oon runs into vinegar, or in certain cases to alco- nd vinegar. When gluten is mixed with starch ater, alcohol and vinegar usually make their ap- nce; but the greatest part of the starch remains red. It has been observed that certain substances

are peculiarly efficacious in exciting fermentation in others. These substances have received the name of *ferments*.

But the phenomena of fermentation do not appear in their greatest perfection in our artificial mixture of vegetable principles. Those complicated parts of plants in which various principles are already mixed by Nature, especially the liquid parts, exhibit the finest specimens of it; such as the sap of trees, the juices of fruits, the decoctions of leaves, seeds, &c. It is from such natural mixtures that we obtain all the products of fermentation which mankind have applied to useful purposes; such as indigo, beer, bread, vinegar, wine, &c. In the present imperfect state of the subject, I shall satisfy myself with an account of the most important of these products of fermentation, and of the phenomena which take place during their formation.

Division. I shall divide this Chapter into four Sections: In the first, I shall treat of the fermentation which takes place during the making of bread; in the second, of the fermentation which produces intoxicating liquors; in the third, of the fermentation which produces vinegar; and in the fourth, that which reduces the substance to *soil*. These are usually called the *panary*, *vinous*, *acetous*, and *putrefactive* fermentations.

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SECT. I.

OF THE PANARY FERMENTATION.

.E as the manufacture of bread may appear to us ave been always accustomed to consider it as a on process, its discovery was probably the work s, and the result of the united efforts of men, sagacity, had they lived in a more fortunate pe- f society, would have rendered them the rivals of tle or of Newton. Discovery of bread.

method of making bread similar to ours was in the East at a very early period; but neither ecise time of the discovery, nor the name of the who published it to the world, has been pre- . We are certain that the Jews were acquainted t in the time of Moses: for in Exodus* we find ibition to use leavened bread during the celebra- the passover. It does not appear, however, to een known to Abraham; for we hear, in his his- f cakes frequently, but nothing of leaven. Egypt, om the nature of the soil and the early period at it was civilized, bids fairest for the discovery of g bread. It can scarcely be doubted that the

* Chap. xii. v. 15.

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Jews learned the art from the Egyptians. The Greeks assure us that they were taught the art of making bread by the god Pan. We learn from Homer that it was known during the Trojan war *. The Romans were ignorant of the method of making bread till the year 580 after the building of Rome, or 200 years before the commencement of the Christian era †. Since that period the art has never been unknown in the south of Europe; but it made its way to the north very slowly, and even at present, in many northern countries, fermented bread is but very seldom used.

Substances which make bread.

The only substance well adapted for making bread, I mean *loaf bread*, is wheat flour, which is composed chiefly of *starch* and *gluten*, but contains also some *mucilage* and *saccharine matter*. It is to the gluten that wheat flour owes its superiority to every other as the basis of bread. Indeed there are only two other substances at present known of which loaf bread can be made; these are *rye* and *potatoes*. The rye loaf is by no means so well raised as the wheat loaf; and potatoes will not make bread at all without particular management. Potatoes, previously boiled and reduced to a very fine tough paste by a rolling pin, must be mixed with an equal weight of potatoe starch. This mixture, according to Permentier, if baked in the usual way, makes a very white, well raised, pleasant bread.

Method of baking bread.

The baking of bread consists in mixing wheat flour with water, and forming it into a paste. The average proportion of these is two parts of water to three of flour. But this proportion varies considerably, accord-

* Iliad, ix. 216. † Pliny, lib. xviii. cap. 11.

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ie age and the quality of the flour. In general, r and the better the flour is, the greater is the of water required. If the paste, after being med, be allowed to remain for some time, its nts gradually act upon each other, and the paste new properties. It gets a disagreeable sour id a quantity of carbonic acid gas is evolved. , the paste ferments *. These changes do not ice without water; that liquid, therefore, is a y agent.

fermented dough is known by the name of *lea-* 'rom the experiments of Mr Edlin, it appears ing this fermentation the temperature of the icreases, and that a quantity of vinegar is form- pound avoirdupois of flour mixed with half its of water, and set in a warm place to ferment for x hours, generated as much vinegar as required is of carbonate of potash to neutralize it †.

igh, after standing for a sufficient time to fer- baked in the usual way, it forms a loaf full of e our bread, but of a taste so sour and unplea- t it cannot be eaten. If a small quantity of this e, or *leaven* as it is called, be mixed with new- aste, the whole begins to ferment in a short quantity of gas is evolved: but the glutinous he flour renders the paste so tough that the gas scape; it therefore causes the paste to swell in rection: and if it be now baked into loaves, the e number of air bubbles imprisoned in every

as from this process that Van Helmont transferred the word into chemistry.

's *Treatise on the Art of Bread-Making*, p. 78.

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part renders the bread quite full of eyes, and very light. If the precise quantity of leaven necessary to produce the fermentation, and no more, has been used, the bread is sufficiently light, and has no unpleasant taste; but if too much leaven be employed, the bread has a bad taste; if too little, the fermentation does not come on, and the bread is too compact and heavy. To make good bread with leaven therefore is difficult. Mr Edlin, however, has suggested a method, which, if it do not injure the taste of the bread, may be practised with great facility, and it even improves the lightness of bread. It consists in adding a sufficient quantity of carbonate of potash to neutralize the acetic acid, and to knead the alkali rapidly into the dough, so as to prevent, as much as possible, the carbonic acid disengaged from escaping *.

Fermentation promoted by barm.

The ancient Gauls had another method of fermenting bread. They formed their paste in the usual way; and, instead of leaven, mixed with it a little of the *barm* which collects on the surface of fermenting beer†. This mixture produced as complete and as speedy a fermentation as leaven; and it had the great advantage of not being apt to spoil the taste of the bread. About the end of the 17th century, the bakers in Paris began to introduce this practice into their processes. The practice was discovered, and exclaimed against; the faculty of medicine, in 1688, declared it prejudicial to health; and it was not till after a long time that the bakers succeeded in convincing the public that bread baked with

* Edlin's *Treatise on the Art of Bread-Making*, p. 79.
† Pliny, lib. xviii. cap. 7.

is superior to bread baked with leaven. In this Chap. IV.
ry the bread has for these many years been fer-
d with barm.

hat is this barm which produces these effects? Mr
y of Manchester has proved, by a number of very
sting experiments, that carbonic acid is capable of
employed in many cases with success as a substi-
or barm *. Edlin informs us, that when dough
ed with water impregnated with carbonic acid, the
ises precisely as when yeast is used; and he assures
at yeast, previously deprived of its carbonic acid
at, has no efficacy in raising bread; but that it
in the usual way, and becomes full of eyes, if the
us separated be again added †. Hence he con-
that carbonic acid is the only essential consti-
of yeast, as far as the *raising* of bread is con-
l.

at the presence of carbonic acid, or of some simi-
s, is essential, cannot be doubted; but there is
to doubt the assertion, that yeast, after being de-
d of its carbonic acid, will not afterwards, when
ened, generate a sufficient quantity to answer all
irposes required. It has been customary with the
s of Paris to bring their barm from Flanders and
dy in a state of dryness. When skimmed off the
it is put into sacks, and the moisture allowed to
out; then these sacks are subjected to a strong
ure, and when the barm is dry it is made up into
‡. Now this process must separate the carbonic

* *Manch. Mem.* ii. 162.
† Edlin's *Treatise on the Art of Bread-Making*, p. 54.
‡ *Encycl. Method. Arts et Met.* i. 249.

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acid; yet this barm, when again moistened, ferments bread equally well with new barm.

After the bread has fermented, and is properly raised, it is put into the oven previously heated, and allowed to remain till it be baked. The mean heat of an oven, as ascertained by Mr Tillet, is 448° *. The bakers do not use a thermometer: but they judge that the oven has arrived at the proper heat when flour thrown on the floor of it becomes black very soon without taking fire. We see, from Tillet's experiment, that this happens at the heat of 448°.

Quantity of bread from a given weight of flour.

A sack of flour containing five bushels, and weighing 280 lbs. avoirdupois, is in this country made, at an average, into 80 quartern loaves. Hence $3\frac{1}{2}$ lbs. of flour go to every loaf. From the evidence laid before a Committee of the House of Commons in 1804, we learn that for this quantity of flour five pounds avoirdupois of common salt, and about three English pints of good yeast, are allowed. There is reason to believe, also, that about an ounce of alum, previously dissolved in water, is mixed with the yeast †. After the dough has been properly kneaded and fermented, it is divided into masses, weighing each 4 lbs. 15 ounces avoirdupois; the quantity of wet dough allowed for a quartern loaf. It is then put into the oven, and when sufficiently baked is withdrawn. By the laws of this country, every quartern loaf must weigh 4 lbs. $5\frac{1}{2}$ ounces avoirdupois. Hence we see that it loses about $11\frac{1}{2}$ ounces while in the oven. The number of loaves obtained from a sack of flour varies a good deal; sometimes 82

* *Encyc. Method. Arts et Metiers*, i. 275.

† Edlin, p. 90.

s can be made from it, sometimes scarcely 80, de- ing obviously on the quality of the flour *. Chap. IV.

Loss sustained in the oven.

appears, from the report of the commissioners of French Academy in 1783, that French bread loses er more weight than what has been above stated. Tillet, and the other commissioners who were ap- ted to examine this subject in consequence of a pe- n from the bakers of Paris, found that a loaf, ch weighed before it was put into the oven 4·625 nds, after being taken out baked, weighed, at an age, only 3·813 pounds, or 0·812 pound less than paste. Consequently 100 parts of paste lose, at verage, 17·34 parts, or somewhat less than $\frac{1}{5}$th, by ng †. They found, however, that this loss of ght was by no means uniform, even with respect hose loaves which were in the oven at the same , of the same form, and in the same place, and ch were put in and taken out at the same instant. greatest difference in these circumstances amount- ·2889, or 7·5 parts in the hundred, which is about of the whole. This difference is very considerable, it is not easy to say to what it is owing. It is evi- , that if the paste has not all the same degree of ture, and if the barm be not accurately mixed igh the whole, if the fermentation of the whole be precisely the same, that these differences must take e. Now, it is needles to observe how difficult it perform all this completely. The French com- ioners found, as might indeed have been expected,

* For a minute description of the method of baking bread, the reader rred to Edlin's *Treatise on Bread-Making*, p. 90.

† *Encyc. Method. Arts et Metiers*, i. 275.

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that, other things being equal, the loss of weight sustained is proportional to the extent of surface of the loaf, and to the length of time that it remains in the oven; that is to say, the smaller the extent of the external surface, or, which is the same thing, the nearer the loaf approaches to a globular figure, the smaller is the loss of weight which it sustains; and the longer it continues in the oven, the greater is the loss of weight which it sustains. Thus a loaf which weighed exactly four pounds when newly taken out of the oven, being replaced as soon as weighed, lost, in ten minutes, ·125 pound of its weight, and in ten minutes more it again lost ·0625 pound *.

Loaves are heaviest when just taken out of the oven; they gradually lose part of their weight, at least if not kept in a damp place, or wrapt round with a wet cloth †. Thus Mr Tillet found that a loaf of four pounds, after being kept for a week, wanted ·3125, or nearly $\frac{1}{13}$th of its original weight ‡.

Properties of bread.

When bread is newly taken out of the oven, it has a peculiar, and rather pleasant smell, which it loses by keeping, unless its moisture be preserved by wrapping it round with a wet cloth; as it does also the peculiar taste by which new bread is distinguished. This shows us that the bread undergoes chemical changes; but what these changes are, or what the peculiar substance is to which the odour of bread is owing, is not known.

Bread differs from the flour of which it is made, for

* *Encyc. Method.* art. i. 270.

† This is an excellent method of preserving bread fresh, and free from mould for a long time.

‡ *Encyc. Method.* art. i. 270.

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none of the ingredients of the flour can now be discovered in it. The only chemist who has attempted an analysis of bread is Mr Geoffroy. He found that 100 parts of bread contained the following ingredients:

Constituents of bread.

24·735 water
32·030 gelatinous matter, extracted by boiling water
39·843 residuum insoluble in water

96·608
3·392 loss

100·000

But this analysis, which was published in the Memoirs of the French Academy for the year 1732, was made at a time when the infant state of the science of chemistry did not admit of any thing like accuracy. It is by no means improbable, that if bread were to be examined with care, both the gluten and starch might still be detected, though perhaps it would be difficult to separate them.

SECT. II.

OF THE VINOUS FERMENTATION.

Under this name is comprehended every species of fermentation which terminates in the formation of an intoxicating liquid. Now these liquids, though numerous, may be comprehended under two general heads; namely, those which are obtained from the *de-*

Book IV. *coctions of seeds*, and those which are obtained from the *juices of plants*. The liquids of the first class are denominated *beer* or *wash*, those of the second *wine*.

I. Beer.

The method of making beer was known in the most remote ages. The Greek writers give the honour of the invention to the Egyptians. Almost every species of corn has been employed for the purpose. In Europe it is usually made from barley, in India from rice, in the interior of Africa from the *holcus spicatus* *; but whatever grain is employed, the process is nearly the same. We shall therefore select, as an example, the beer made in this country from *barley*.

1. As the grain in its natural state has been found unsuitable for yielding good beer, it is usual, in the first place, to convert it into *malt*.

Malt.

The term *malt* is applied to grain which has been made to germinate artificially to a certain extent, after which the process is stopped by the application of heat.

Steeping of barley.

The barley is steeped in cold water for a period which (as regulated by law) must not be less than 40 hours; but beyond that period the steeping may be continued as long as is thought proper. Here it imbibes moisture, and increases in bulk; while at the same time a quantity of carbonic acid is emitted, and a part of the substance of the husk is dissolved by the steep-water. The proportion of water imbibed depends

* Park's *Travels*, p. 63, 8vo Edition.

y on the barley, and partly on the length of time it is steeped. From the average of a good many , it appears that the medium increase of weight, steeping, may be reckoned 0·47; that is to say, y 100 pounds of barley when taken out of the weighs 147 pounds. The average increase of is about a fifth; that is to say, that 100 bushels rain, after being steeped, swell to the bulk of 120 els. The carbonic acid emitted while the barley is e steep is inconsiderable; and it is probable, from xperiments of Saussure, that it owes its formation, ast in part, to the oxygen held in solution by the -water.

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he steep-water gradually acquires a yellow colour, the peculiar smell and taste of water in which y has been steeped. The quantity of matter which lds in solution varies from $\frac{1}{50}$th to $\frac{1}{100}$th of the ht of the barley. It consists chiefly of an extractmatter of a yellow colour and disagreeable bitter , which deliquesces in a moist atmosphere, and ins always a portion of nitrate of soda. It holds lution most of the carbonic acid disengaged. This ctive matter is obviously derived from the husk e barley, and is the substance to which that husk its colour. Accordingly grain becomes much by steeping.

Couch.

fter the grain has remained a sufficient time in the , the water is drained off, and the barley thrown f the cistern upon the malt-floor, where it is formto a rectangular heap, called the *couch*, about 16 es deep. In this situation it is allowed to remain ut 26 hours. It is then turned, by means of wooden vels, and diminished a little in depth. This turn-

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ing is repeated twice a-day or oftener, and the grain is spread thinner and thinner, till at last its depth does not exceed a few inches.

Changes while on the malt-floor.

When placed on the couch, it begins gradually to absorb oxygen from the atmosphere, and to convert it into carbonic acid; at first very slowly, but afterwards more rapidly. The temperature, at first the same with that of the external air, begins slowly to increase; and in about 96 hours the grain is, at an average, about 10° hotter than the surrounding atmosphere. At this time the grain, which had become dry on the surface, becomes again so moist that it will wet the hand, and exhales at the same time an agreeable odour, not unlike that of apples. The appearance of this moisture is called *sweating*. A small portion of alcohol appears to be volatilized at this period. The great object of the maltmen is to keep the temperature from becoming excessive. This they do by frequent turning. The temperature which they wish to preserve varies from 55° to 62°, according to the different modes of malting pursued.

At the period of the sweating the roots of the grains begin to appear, at first like a small white prominence, at the bottom of each seed, which soon divides itself into three rootlets, and increases in length with very great rapidity, unless checked by turning the malt. About a day after the sprouting of the roots, the rudiments of the future stem, called *acrospire* by the maltsters, may be seen to lengthen. It rises from the same extremity of the seed with the root, and advancing within the husk, at last issues from the opposite end: but the process of malting is stopped before it has made such progress.

As the acrospire shoot [illegible] e grain, the appear-

kernel, or mealy part of the corn, under- Chap. IV.
derable change. The glutinous and muci-
itter is taken up and removed, the colour
ite, and the texture so loose that it crumbles
etween the fingers. The object of malting
e this change: when it is accomplished,
place when the acrospire has come nearly
f the seed, the process is stopped by drying
on the kiln. The temperature at first does
00°; but it is raised very slowly up to 140°,
according to circumstances. The malt is
l, to separate the rootlets, which are consi-
urious.

short sketch of the process of malting. being converted into malt, generally in- or three *per cent.* in bulk; and loses, at an ut a fifth of its weight, or 20 *per cent.* But parts 12 are to be ascribed to kiln-drying, of water, which the barley would have lost exposed to the same temperature: so that does not exceed eight *per cent.* From a trials, made with as much attention to all stances as possible, the following seems to of accounting for this loss:

Loss sustained in malting.

ed off by the steep-water	1·5
pated in the floor	3·0
s, separated by cleaning	3·0
e	0·5
	8·0

on the floor ought to be entirely owing to ion of carbon by the oxygen of the atmo- t were this the only cause, it would be much

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smaller than three *per cent.* Two other causes concur to produce this loss: 1. Many of the roots are broken off during the turning of the malt; these wither and are lost, while others grow in their place: 2. A certain portion of the seeds lose the power of germinating, by bruises or other accidents, and these lose a much greater portion than three *per cent.* of their real weight. From a good many trials, made with as much care as possible, I am disposed to conclude that the quantity of carbon, separated during the whole process of malting, by the formation of carbonic acid gas, does not exceed two *per cent.* and that the weight of the roots formed amounts often to four *per cent.* These two, in reality, include the whole real loss of weight which barley sustains when malted. What is lost in the steep, being husk, need scarcely be reckoned.

The roots appear, from the process, to be formed chiefly from the mucilaginous and glutinous parts of the kernel. The starch is not employed in their formation; but undergoes a change, intended no doubt to fit it for the future nourishment of the plumula. It acquires a sweetish taste, and the property of forming a transparent solution with hot water. In short, it approaches somewhat to the nature of sugar; but is much more soluble, and much more easily decomposed, than that principle. No doubt it is by the abstraction of carbon, which takes place on the malt floor, that this change is brought about. The action of hot water on barley meal seems gradually to induce a similar one.

Brewing.

2. Malt thus prepared is ground in a mill, and infused in a large cylindrical vessel, called the *mash-tun*, with somewhat more than its own bulk of water, of a temperature varying from 160° to 180°, according to

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y of the brewer. The infusion is left covered or three hours, and then the liquid drawn off ck at the bottom of the vessel. More hot waterwards added, and the infusions repeated in a manner, till the malt is sufficiently exhausted.

Constituents of wort.

liquid thus obtained is called *wort*. It has a colour, a luscious sweet taste, a peculiar smell, en the process is properly conducted is perfectly rent. It consists of the water employed holding aly part of the malt in solution. When exay reagents, it appears to consist chiefly of four t substances held in solution together: namely, eet tasted substance, to which the name of *sacmatter* has been given. It is by far the greatoint of quantity. This substance when separa a light brown colour; when dried at 160°, it a brittle mass with a glazed surface; at the ture of 180°, or a little higher, its colour bedarker; and if we keep it in that temperature, ing it occasionally, it becomes at last almost loses its sweet taste altogether, and acquires a disagreeable one. In a temperature somewhat but under the boiling point, it is charred. It is luble in water, and if once dissolved can scarcerecovered again by evaporation without consi loss. Alcohol dissolves it very imperfectly nd when heat is applied it deprives the alcohol rtion of water, and forms a tough mass like tur, which refuses to dissolve. The specific grathis saccharine matter is 1·552. It appears to essential constituent of wort. 2. Starch. The ce of this substance is easily detected by dropping usion of nutgalls into wort; a precipitate appears,

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which is mostly redissolved by heating the liquid to 120°. 3. The insoluble part of the precipitate is a combination of gluten and tannin. The proportion of gluten in wort is very inconsiderable. That of the starch probably diminishes in proportion as the barley is more completely malted. I have detected starch in pretty old and perfectly transparent ale; but the gluten had disappeared. New ale, however, often contains traces of it. 4. The fourth ingredient in wort is *mucilage*, which precipitates in flakes when the wort is dropt into alcohol. Its quantity is more considerable in the worts last drawn off than in the first worts.

The wort is boiled with a quantity of hops, which vary considerably, but which may be stated in general at about $\frac{1}{75}$th of the weight of the malt. When sufficiently concentrated, it is thrown into very wide flat vessels called *coolers*, placed in the most open situation that can be had. Here it is cooled down to the temperature of about 52°, and then let down into a deep round wooden vessel called the *fermenting tun*. The specific gravity of the wort when put into the fermenting tuns varies very much. The wort of strong ale is sometimes as low as 1·070 (or perhaps even lower); sometimes as high as 1·127. In the first case it contains 16·6 *per cent*. of solid matter; in the second 28·9 *per cent*. The wort of small beer varies from 1·015 to 1·040; the first containing not quite 3·5 *per cent*. and the second about 9·5 *per cent*. of solid matter.

Hops.

The use of the hops is partly to communicate a peculiar flavour, from the oil which they contain; partly to cover the sweetness of saccharine matter by the bitter principle which they contain; and partly to counteract the tendency which wort has to run into acidity.

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f the wort be let down into the fermenting tun at temperature of 60°, or rather higher, the substances ich it holds in solution begin gradually to act upon h other, and to decompose each other. The tempe- are rises, an intestine motion takes place, a scum ects on the surface, and carbonic acid gas is emit- . This intestine motion is called *fermentation*. The position of wort to ferment is not sufficiently great induce it with the requisite rapidity. It takes place slowly and imperfectly, that the liquor runs into aci- y before the formation of ale has made sufficient pro- ss. To prevent this, it is requisite to add to the rt some substance which has the property of indu- g speedy fermentation. The substance made choice is *yeast*, or the frothy matter which collects on the face of the beer while fermenting. The quantity of ast used by brewers is but small, generally about a lon to every three barrels of the wort.

The yeast thus added appears to act chiefly upon saccharine matter held in solution in the wort, to compose it while it undergoes partial decomposition elf. By this mutual action the saccharine matter dis- pears, the specific gravity of the wort diminishes, and properties alter, being converted into the intoxica- g liquor called *ale*. During this mutual action the mperature of the liquid increases, and the increase pends upon the violence of the fermentation. In ale orts the rise of temperature is but small, amounting an average to about 15°, because the quantity of ast is small; but in the fermentation of wash, it oft- amounts to 50°, or even more in some cases.

Analysis of yeast.

Considerable exertions have been made by chemists, f late, to ascertain the nature of the substance in yeast

which produces this striking effect upon wort, and to discover it if possible in other substances. Westrumb examined the yeast of beer. From 15360 parts of it he obtained the following substances:

Potash	13
Carbonic acid	15
Acetic acid	10
Malic acid	45
Lime	69
Alcohol	240
Extractive	120
Mucilage	240
Saccharine matter	315
Gluten	480
Water	13595
	15142

Besides some traces of phosphoric acid and of silica*. But it is obvious, that all these ingredients are not essential. From the experiments of Westrumb, it appears that when the yeast is filtered, a matter remains upon the filter which possesses the properties of gluten; that when this substance is separated the yeast loses the property of exciting fermentation, but recovers it again when the gluten is added. Hence it follows that this glutinous matter is the essential constituent of the yeast.

Gluten its essential constituent.

When yeast is kept for some time in cylindrical glass vessels, a white substance not unlike curd separates, and swims upon the surface. If this substance be removed, the yeast loses the property of exciting fermentation.

* Crell's *Annals*, 1796, i. 13.

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ubstance possesses many of the properties of glu- ough it differs from it in others. Its colour is whiter; it has not the same elasticity; and its par- do not adhere with the same force. It dissolves eadily in acids. I have little doubt that this is rt of yeast which is the real ferment. It may be ered as gluten somewhat altered, and much more ed to decomposition. It existed, no doubt, in the rain, but underwent considerable modifications the process of malting, and probably others du- e fermentation of the beer from which it sepa-

t a substance analagous to gluten is the real fer- appears also from the experiments of Fabroni, ublished a Treatise on Wine-making in 1785, gained the prize proposed by the Florence Aca- By heating the juice of grapes, and passing it h a filter, he separated an adhesive matter which sed the properties of gluten. The juice deprived substance refused to ferment, but it fermented al when the glutinous matter was again added. bservations of Thenard confirm those of Fabroni. und in the juices of all fruits examined, a sub- similar to that described by Fabroni, and which, ing to him, is absolutely the same with pure This substance is insipid, does not change ve- e blues, is insoluble in water, loses $\frac{3}{4}$ths of its t when dried, and is decomposed like animal nces. When eight parts of it were distilled, they 83 of charcoal, and yielded 1·61 of water, 1·31 and a quantity of ammonia, which, when satu- with muriatic acid, formed 1·46 of sal-ammo- the gas obtained weighed 0·33, and consisted of

Book IV. $\frac{1}{5}$th carbonic acid, and $\frac{4}{5}$ths of carbureted hydrogen, requiring $1\frac{1}{5}$ times its bulk of oxygen to consume it. Nitric acid, even when diluted, converts it into a species of tallow. With potash it forms a soap, while ammonia is disengaged. When mixed with sugar and a sufficient quantity of water, fermentation takes place, carbonic acid is disengaged, and a vinous liquor formed. By this action the ferment loses the whole of its azote, and becomes incapable of exciting fermentation when mixed with a new portion of sugar *.

The essential constituent of yeast, then, may be considered as a species of gluten, differing in several respects from the gluten of wheat. When mixed with the wort, this substance acts upon the saccharine matter; the temperature rises, carbonic acid is disengaged, and the saccharine matter is converted into ale. The yeast soon collects on the top of the liquid, but the brewer occasionally mixes it again to continue the fermentation. The quantity of yeast employed being small, the saccharine matter is but imperfectly decomposed.

Ale. Hence a considerable portion of it still remains in the ale, and gives it that glutinousness and body for which it is remarkable. The specific gravity of ale varies very much according to the original strength of the wort, and the extent to which the fermentation has been carried. The limits may be stated at about 1·035 and 1·012.

The properties of ale are so well known that no description is deemed necessary. As it possesses intoxicating qualities, it has been considered as holding alco-

* Thenard, *Ann. de Chim.* xlvi. 308.

hol in solution; but this is by no means proved. It is true, that when distilled it yields alcohol; but this, as Berthollet has observed, may be in consequence of a decomposition brought about by the heat *. It is certain that the intoxicating quality of ale is by no means proportional to the quantity of alcohol which it yields when distilled.

II. Wash.

Ale being intended as an article of food, and its value depending in a great measure on its flavour and appearance, particular attention is paid to obtain these in as great perfection as possible. But there is another species of ale which is brewed by the distillers for the express purpose of procuring from it ardent spirits by a subsequent process. The method which they follow is in several respects different. In particular, they endeavour to carry the fermentation to as great a length as possible, because the quantity of spirits is proportional to the saccharine matter decomposed, whatever remains unaltered yielding none. It is here, therefore, that the effects of fermentation can be best observed.

Brewing.

1. In this country the distillers do not brew from pure malt; they use chiefly raw grain. The proportion of malt varies from a third to a tenth part of the raw grain employed. This mixture they grind to meal, infuse with water at a heat considerably lower than that of the water used by the brewers, and employ much more agitation to mix it completely. The wort is drawn off and cooled

* *Statique Chemique*, ii. 528.

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in the usual way, and fresh water poured on to exhaust the grain.

The wort thus formed is not so transparent as that from malt, but its taste is nearly as sweet. It would appear, therefore, that the starch in the raw grain undergoes a certain change during the mashing, and is brought towards the state of saccharine matter.

In this country, where the duty is levied chiefly upon the *wash* *, the distillers make the specific gravity of their wort as high as from 1·084 to 1·110: this they do not by boiling, but by *lobbing*; that is, by preparing a strong infusion of the flour of malt, or of barley and malt and hot water, and adding this almost saturated solution to the wort till it has acquired the requisite strength. But in Holland, where the duties are levied in a different way, the specific gravity of the wort is much lower.

Fermentation.

The wort thus made is let down into the fermenting tun at a temperature varying from 55° to 70°, according to the quantity, the season, the goodness of the yeast, and the skill of the distiller. Here it is mixed successively with considerable portions of the best yeast that can be procured, and the fermentation is urged as far as it can be made to go. The process lasts about ten days, and the temperature rises usually to between 90° and 100°, and sometimes even higher. Great quantities of carbonic acid are disengaged, and the liquid becomes specifically lighter; sometimes sinking to 1·000, and usually to from 1·007 to 1·002. The success of the fermentation is estimated by this loss of specific gravity.

* This is the name given to the fermented wort of distillers.

The wash thus prepared is distilled. What comes over first is denominated *low wine*, and is concentrated by a second distillation.

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This fermentation is obviously the consequence of the action of the peculiar ferment in yeast upon the saccharine matter of the wort. Even when the fermentation is carried to its greatest extent, it does not appear that the whole solid matter held in solution by the wort is decomposed. Nine trials were made upon the wort of pure malt; in all of them the fermentation went on pretty successfully, as may be seen from the following Table:

Always incomplete.

Specific gravity of the wort.	Specific gravity of the wash.
1·040	1·0014
1·056	1·0016
1·050	1·000
1·0492	1·0012
1·0465	1·0045
1·045	1·0047
1·0465	1·0007
1·051	1·0007
1·0524	1·0004

When a portion of these different liquids was evaporated to dryness, the quantity of solid matter which it left was found to amount to $\frac{1}{7}$th, at an average, of the original quantity. Thus $\frac{6}{7}$ths had been decomposed by the fermentation, and $\frac{1}{7}$th still remained. This matter was still capable of fermentation, when redissolved in water and mixed with fresh yeast. On comparing the quantity of alcohol of 0·825, obtained in these trials, with the weight of solid matter of the malt which had been decomposed by the fermentation,

Book IV. the result was, that every pound weight of solid matter, so decomposed, furnished almost exactly half a pound of alcohol, of the specific gravity 0·825.

When sugar, dissolved in four times its weight of water, and mixed with yeast, is placed in the proper temperature, it ferments precisely as wort does, and yields the same products. It has been employed, therefore, by chemists as a less complicated means of ascertaining the phenomena of fermentation. Thenard mixed 60 parts of yeast with 300 of sugar, and fermented them in the temperature of 59°. In four or five days, he informs us, that all the saccharine matter had disappeared *. The quantity of carbonic acid evolved amounted, by weight, to 94·6 parts. It was perfectly pure, being completely absorbed by water †. The fermented liquid, being distilled, yielded 171·5 parts of alcohol, of the specific gravity ·822. When the residue of the distillation was evaporated, 12 parts of a nauseous acid substance were obtained; and 40 parts of the yeast still remained; but, upon examination, it had lost the whole of its azote. This experiment gives us the following quantities:

Produce.

1. *Substances fermented.*

Sugar..............	300
Yeast..............	60
	360

* There is reason to doubt the precision of this assertion, as it never happens in the great scale, where every thing is much more favourable.

† The very pungent aromatic odour which carbonic acid has when disengaged from the fermenting tun, shows that it contains a portion of the wash; and this has been verified by actual experiment.

2. Products of fermentation.

Alcohol of ·822	171·5
Carbonic acid	94·6
Nauseous residue	12·0
Residual yeast.........	40·0
	318·1
Loss...................	41·9

The loss here amounts to about a ninth part of the whole, and must either be ascribed to waste, or to the formation of water. The first is the more probable supposition. From this experiment, we learn that 100 parts of sugar, supposing the yeast not to furnish any thing, would yield,

Alcohol	57·16
Carbonic acid	31·53
Nauseous residue	4·00
	92·69
Loss..................	7·31

Here the produce of alcohol is greater than that obtained from wort of barley; but the produce of carbonic acid is somewhat less. The well-known experiment of Lavoisier corresponds pretty well with the result obtained by Thenard. 100 pounds of sugar and 10 of yeast yielded,

Alcohol	57·70
Carbonic acid.........	35·34
Residue...............	6·59
	99·63

These experiments are sufficient to show us, that by far the greatest part of the produce is obtained from

the sugar. The yeast acts chiefly by inducing the decomposition of that substance; but as it loses its azote, and in part disappears, we must allow it to furnish a portion of the new substances formed.

Seguin has endeavoured to prove that the essential constituent of yeast is not gluten, but albumen. It must be observed, however, that the nature of vegetable albumen is by no means well defined. Fabroni found that the albumen of eggs does not act as a ferment. It is clear that vegetable albumen differs exceedingly from animal; and I have no doubt that the same substance has been described by Thenard and Seguin under different names.

Whether an acid be necessary for fermentation.

Fabroni found that the gluten of wheat acted but imperfectly as a ferment; but that its efficacy was much improved by the addition of tartar. Berthollet repeated these experiments successfully. He ascribes the efficacy of tartar to the property which it has of promoting the solubility of the gluten. The presence of an acid was supposed formerly to be necessary for fermentation; but this does not seem to be the case. It is true, indeed, that an acid usually makes its appearance during fermentation. The formation of this acid has been ascribed to the action of the yeast upon the mucilaginous or starchy parts of the wort: but from the experiments of Fourcroy and Vauquelin, it appears that it always makes its appearance when wort is fermented without any yeast. In these trials they obtained only vinegar, and no alcohol. When the wort, either of raw grain or of malt, is fermented at the temperature of 80°, without any yeast, the gas which comes over consists of one-half carbonic acid and one-

alf hydrogen; but at a lower temperature pure malt-vort does not yield any inflammable gas *. Chap. IV.

III. Wine.

There is a considerable number of ripe fruits from which a sweet liquor may be expressed, having at the ame time a certain degree of acidity. Of such fruits we have in this country the apple, the cherry, the goose-erry, the currant, &c. but by far the most valuable of hese fruits is the *grape*, which grows luxuriantly in the outhern parts of Europe. From grapes, fully ripe, may e expressed a liquid of a sweet taste, to which the ame of *must* has been given. This liquid is composed lmost entirely of five ingredients; namely, *water*, *su-ar*, *jelly*, *gluten*, and *tartaric* acid partly saturated ith potash. The quantity of sugar which grapes fully pe contain is very considerable; it may be obtained in ystals by evaporating must to the consistence of sy-p, separating the tartar which precipitates during evaporation, and then setting the must aside for e months. The crystals of sugar are gradually form-. From a French pint of must, the Marquis de lion extracted half an ounce (French) of sugar, and unce of tartar ‡. According to Proust, the Musca-grape contains about 30 *per cent*. of a peculiar spe-of sugar §.

Fruits affording wine.

Must.

hen must is put into the temperature of about 70°, ifferent ingredients begin to act upon each other, hat is called *vinous fermentation* commences. The

Undergoes the vinous fermentation.

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n. des Mus. d'Hist. Nat. vii. 16.
lion, Jour. de Phys. xxix. 3. † Ibid. p. 5. § Ibid. lvi. 113.

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phenomena of this fermentation are an intestine motion in the liquid; it becomes thick and muddy, its temperature increases, and carbonic acid gas is evolved. In short, the very same changes take place as have been remarked when describing the fermentation of ale. In a few days the fermentation ceases, the thick part subsides to the bottom, or rises to the surface, the liquid becomes clear, it has lost its saccharine taste, and assumed a new one; its specific gravity is diminished; and it has become the liquid well known under the name of *wine*.

As this fermentation takes place without adding any *ferment*, it is obvious that the requisite substance is present in the juice. This substance was separated, and found by Fabroni to be analogous to the gluten of plants; and gluten being substituted for it, the fermentation succeeded. Fabroni has shown that the saccharine part of must resides in the cells of the grapes; while the glutinous matter, or ferment, is lodged on the membranes that separate the cells. Hence it follows, that in the fruit these two substances are not in contact. It is only after the juice is squeezed out that they are mixed. All other juices which undergo a spontaneous fermentation at the requisite temperature, have been shown by Thenard and Seguin to contain a similar substance. The formation of wine, then, is owing to the action of this glutinous matter on the saccharine substance of the juice, precisely as happens in the fermentation of ale.

All those juices of fruits which undergo the vinous fermentation, either with or without the addition of sugar, contain an acid. We have seen already in the First Chapter, that the vegetable acids are obtained chiefly

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n fruits. The apple, for instance, contains ma-
l; the lemon, citric acid; the grape, tartaric and
acids. The Marquis de Bullion has ascertained
ust will not ferment if all the tartar which it con-
e separated from it; but it ferments perfectly
restoring that salt *. The same chemist ascer-
that the strength of wine is considerably increa-
adding tartar and sugar to the must †. We may
le from these facts, that the presence of a vege-
cid is of importance in these spontaneous fermen-
. It deserves attention, that Bullion obtained
artar from verjuice than from wine; and he ob-
that the more the proportion of sugar in grapes
ed, the more that of tartar diminished ‡.
ems more than probable, from the experiments
lion and Chaptal, that the tartaric acid is partly
osed during the fermentation, and that a por-
malic acid is formed. The process, therefore, is
omplicated than was suspected by Lavoisier. It
ously analogous to combustion, as is evident
e evolution of caloric and the formation of car-
cid, which is a product of combustion. Proust
ertained that, during the fermentation, not only
c acid, but azotic gas also, is disengaged. This
nonstration, that all the constituents of must are
ed; for sugar does not contain that principle §.
d could detect no azote in the carbonic acid from

r the fermentation has ceased, the liquor is put

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r. de Phys. xxix. 4.—But the addition of salt of wood sorrel did
te the fermentation.

† *Ann. de Chim.* xxxvi. 26.

r. de Phys. xxix. 4.

§ Ibid. lvi. 115.

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into casks, where the remainder of the sugar is decomposed by a slow fermentation; after which the wine, decanted off the extractive matter, is put up in bottles.

Component parts of wine.

The properties of wine differ very much from each other, according to the nature of the grapes from which the must was extracted, and according to the manner in which the process was conducted. These differences are too well known to require a particular description. But all wines contain less or more of the following ingredients; not to mention water, which constitutes a very great proportion of every wine.

An acid,

1. *An acid.*—All wines give a red colour to paper stained with turnsole, and of course contain an acid. Chaptal has ascertained that the acid found in greatest abundance in wine is the malic, but he found traces also of citric acid; and it is probable that wine is never entirely destitute of tartar. All wines which have the property of frothing when poured into a glass contain also carbonic acid, to which they owe their briskness. This is the case with champagne. These wines are usually weak; their fermentation proceeds slowly, and they are put up in close vessels before it be over. Hence they retain the last portions of carbonic acid that have been evolved.

Alcohol,

2. *Alcohol.*—All wine contains less or more of this principle, to which it is indebted for its strength; but in what particular state of combination it exists in wine cannot easily be ascertained. It is undoubtedly intimately combined with the other component parts of wine; as Fabroni has shown that it cannot be separated by saturating the wine with dry carbonate of potash, though a very small portion of alcohol, added

pose to wine, may be easily separated by means of t salt. But if alcohol separates along with the car- ic acid during the fermentation, we can scarcely bt that it has been formed. When wine is distilled, alcohol readily separates. The distillation is usu- continued as long as the liquid which comes over nflammable. The quantity obtained varies accord- to the wine, from a fourth to a fourteenth part of wine distilled. The spirit thus obtained is well wn under the name of *brandy*. Bullion has ob- ved, that when wine is distilled new it yields more hol than if it be allowed to get old *. What re- ns after this distillation is distinguished in France the name of *vinasse*. It consists of tartar, &c. and en evaporated to dryness, and subjected to combus- , yields potash.

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. *Extractive matter*.—This matter exists in all es: but its proportion diminishes according to the of the wine, as it gradually precipitates to the bot- .

Extract,

. Every wine is distinguished by a peculiar flavour odour, which probably depends upon the presence volatile oil, so small in quantity that it cannot be arated.

Oil,

. The *colouring matter* of wine is originally con- ed in the husk of the grape, and is not dissolved till alcohol be developed. This matter is analogous to other colouring matters of plants: a set of bodies sessed of remarkable properties, but too little exa- ed hitherto to be introduced with much advantage

And colouring matter.

* *Jour. de Phys.* xxix. 6.

quart of	Highly rectified Spirit.			Thick, oily, unctuous, resinous matter.			Gummy and tartarous matter.			Water.			
	oz.	dr.	gr.	oz.	dr.	gr.	oz.	dr.	gr.	lb.	oz.	dr.	gr
nd	1	6	00	3	2	00	1	5	00	2	5	3	00
ant	3	6	00	6	0	20	0	1	40	2	2	6	00
gundy	2	2	00	0	4	00	0	1	40	2	9	0	20
assone	2	6	00	0	4	10	0	1	20	2	8	4	30
mpagne	2	5	20	0	6	40	0	1	00	2	8	3	00
ch	3	0	00	0	6	40	0	1	00	2	8	0	20
tignac	3	0	00	3	4	00	0	5	20	2	4	6	30
Grave	2	0	00	0	6	00	0	2	00	2	9	0	00
nitage	2	7	00	1	2	00	0	1	40	2	7	5	20
eira	2	3	00	3	2	00	2	0	00	2	4	3	00
nsey	4	0	00	4	3	00	2	3	00	2	1	2	00
de ite iano	2	6	00	0	3	00	0	2	40	2	8	0	20
lle	2	2	00	0	4	20	0	1	30	2	9	0	10
dine	3	0	00	2	4	00	1	0	00	2	5	4	00
chatel	3	2	00	4	0	00	1	7	00	2	2	7	00
Sec	2	3	00	2	4	00	4	4	00	2	2	5	00
c	2	0	00	0	5	20	0	2	00	2	9	0	40
henish	2	0	00	1	0	00	0	2	20	2	8	5	40
sh	2	2	00	0	3	20	0	1	34	2	9	1	06
anca	3	0	00	3	4	00	2	0	00	2	3	4	00
y	3	0	00	6	0	00	2	2	00	2	0	6	00
sh	1	2	00	2	4	00	9	4	00	1	10	6	00
Tinto	3	0	00	6	4	00	1	6	00	2	0	6	00
y	2	2	00	4	3	00	5	0	00	2	0	3	00
ol red ne	1	4	00	1	2	00	0	4	00	2	8	6	00
wine	1	6	00	0	4	40	0	2	20	2	9	3	20
ite	2	0	00	0	7	00	0	3	00	2	7	0	00

To this head belong not only common wine, but all intoxicating liquors made from vegetable juices; as *der* from apples, *perry* from pears, *currant* wine, &c.

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likewise the liquor made from the juice of the sugar cane, the sugar mapple, &c.

SECT. III.

OF THE ACETOUS FERMENTATIONS.

Wine ferments and becomes sour.

If wine or beer be kept in a temperature between 70° and 90°, it gradually becomes thick, its temperature augments, filaments are seen moving through it in every direction, and a kind of hissing noise may be distinguished. These intestine motions gradually disappear, the filaments attach themselves to the sides and bottom of the vessel, and the liquor becomes transparent. But it has now lost its former properties, and is converted into acetous acid. This intestine decomposition has been long distinguished by the name of *acetous fermentation*, because its product is *acetic acid*. That this fermention may take place, certain conditions must be attended to. The most important of these will appear from the following observations:

Alcohol not susceptible of this change.

1. Neither pure alcohol, nor alcohol diluted with water, is susceptible of this change. The weaker the wine or the beer is on which the experiment is made, the more readily is it converted into vinegar: the stronger they are they resist the change with the greater obstinacy. But it results from the experiments of Becher, that strong wines, w[illegible]y are made to undergo the acetous fermentati[illegible] a m[illegible] better and stronger vinegar than w[illegible]

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alcohol, though of itself it refuses to undergo the nge, yet when other bodies are present which readi- ferment, is decomposed during the process, and con- utes to the formation of the acetic acid.

Glutinous matter necessary.

. Wine, entirely deprived of glutinous matter ei- by spontaneous deposition or by clarification, does undergo the acetous fermentation, unless some mu- ginous matter be mixed with it. Chaptal exposed wine destitute of this matter, in open bottles, to the atest summer heat of Montpelier for 40 days, and it did not become sour: but upon adding some vine es to the same wine, it became acid in a few days*. en the water in which gluten of wheat has been wed to ferment is mixed with sugar, the liquid is verted into vinegar without fermentation, without rvescence, and without the contact of air†. The re of this curious change has not been explained.

Carbonic acid formed.

. Wine never becomes sour, provided it be com- ely deprived of all access to atmospheric air. The on is, that during the acetous fermentation the oxy- of the atmosphere is partly converted into carbonic l. It was supposed to have been absorbed; but the experiments of Saussure have shown that this is the case. He found, that when wine was convert- into vinegar in a given portion of air, the bulk was diminished; the quantity of carbonic acid just com- sating the oxygen which had disappeared, except- in as far as that carbonic acid was absorbed by the uid. The quantity of carbonic acid formed during

* Ann. de Chim. xxxvi. 245.

† rcroy and Vauquelin, Ann. de Mus. d'Hist. Nat. vii. 4.

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this conversion of wine into vinegar does not seem to be great; amounting, in Saussure's trials, to about twice the bulk of the wine *. Hence the reason that wine or beer is apt to become sour after the cork has been drawn, and still more apt when part has been poured out of the bottle.

A certain temperature required.

4. A pretty high temperature is necessary for the commencement of the acetous fermentation. Wine or beer (unless very weak) scarcely becomes sour under the temperature of 65° or 70°. The fermentation is very apt to commence when the temperature suddenly rises. It is said, too, that wine and beer are more apt to become sour at certain seasons of the year than at others.

The vinegar-makers in this country keep their wash in stoves, heated to about the temperature of 90°, till the change is completed. From the experiments of Fourcroy and Vauquelin, it appears that vinegar made from grain holds in solution a quantity of gluten, and that a great part of it is separated by heating the vinegar boiling hot. This separation prevents the vinegar from being so apt to spoil.

Effects of the fermentation.

5. When the acetous fermentation is completed, the whole of the malic acid originally contained in the wine has disappeared as well as the alcohol. We must conclude, therefore, that they have been both converted into acetic acid. Part of the glutinous matter has also undergone the same change, and seems indeed to have been the substance that first began the change. Part of it is deposited in the state of flakes; part remains in

* *Recherches Chimique sur la Vegetation*, p. 144.

solution, and disposes the vinegar to decomposition. Vinegar also contains a little tartar, and probably also citric acid. Malic acid is also found in new vinegar; a proof that this part of the wine is the last to undergo the acetous fermentation.

6. From the late experiments of Cadet it appears, that sugar is the essential constituent in liquors to be converted into vinegar, and that the quantity of vinegar formed is proportional to the sugar. But if the sugar exceed an eighth part of the liquid, the whole is not decomposed. 7 water, 1 sugar, and some yeast, ferment in a proper temperature, and form an excellent vinegar *.

Acetic acid formed by other processes.

7. Acetic acid is formed in many other cases of the decomposition of vegetables besides the acetous fermentation. These have been pointed out with much ingenuity by Vauquelin and Fourcroy. They may be reduced under three heads. *First*, When sugar, gum, tartar, wood, &c. are distilled in a retort, or even burnt in the open fire, acetic acid separates in combination with an empyreumatic oil, which gives it a peculiar odour. Hence it was mistaken for other acids, and distinguished by the names of *pyromucous*, *pyrolignous*, *pyrotartarous acids*, till its real name was ascertained by these distinguished chemists †. *Secondly*, When concentrated sulphuric acid is poured upon the same vegetable bodies, they are decomposed in a very different manner; being converted into water, charcoal, and acetic acid. *Thirdly*, Acetic acid is evolved in considerable quantity during the spontaneous decomposition of urine and some

* *Ann. de Chim.* lxii. 248. † Ibid. xxxv. 83.

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other animal substances. Thus it appears that the component parts of acetic acid are extremely apt to combine together in those proportions which constitute that important acid.

SECT. IV.

OF PUTREFACTION.

Nature of putrefaction.

All vegetable substances, both complete plants and their component parts separately, when left entirely to themselves, are gradually decomposed and destroyed, provided moisture be present, and the temperature be not much under 45°, nor too high to evaporate suddenly all the moisture. This decomposition has obtained the name of *putrefaction*.

It proceeds with most rapidity in the open air; but the contact of air is not absolutely necessary. Water is in all cases essential to the process, and therefore is most probably decomposed.

Putrefaction is constantly attended with a fetid odour, owing to the emission of certain gaseous matters, which differ according to the putrefying substance. Some vegetable substances, as gluten and cruciform plants, emit ammonia; others, as onions, seem to emit phosphureted hydrogen gas. Carbonic acid gas and hydrogen gas, impregnated with unknown vegetable matters, are almost constantly emitted in abundance. From the experiments of Saussure, we learn, that when moist wood is left exposed to the air, a portion of the oxygen of the

osphere is converted into carbonic acid; for the Chap. IV.
ntity of this acid formed is just equal to the bulk
the oxygen which disappears. When the experi-
nt is made under receivers, no other gas can be de-
ed except carbonic acid; but in the open air the
od loses a much greater proportion of its weight
n can be accounted for by the carbon thus abstract-
This he ascribes to the escape of oxygen and hy-
gen under the form of water. Hence the quantity
carbon in a given weight of rotten wood is greater
n in the same weight of fresh; but when the putre-
ion goes on in water without the contact of air, the
od becomes white and light, and contains a smaller
portion of carbon than when fresh *. The nature
constituents of vegetable mould, as far as known,
e been detailed in the preceding Chapter. Our che-
cal knowledge of vegetable compounds is still by far
limited to enable us to follow this very complicated
cess of putrefaction with any chance of success.

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* *Recherches Chimiques sur la Vegetation.*

BOOK V.

OF

ANIMALS.

Book V. Animals and vegetables

WHEN we compare animals and vegetables together, each in their most perfect state, nothing can be easier that to distinguish them. The plant is confined to a particular spot, and exhibits no mark of consciousness or intelligence; the animal, on the contrary, can remove at pleasure from one place to another, is possessed of consciousness, and a high degree of intelligence. But on approaching the contiguous extremities of the animal and vegetable kingdom, these striking differences gradually disappear, the objects acquire a greater degree of resemblance, and at last approach each other so nearly, that it is scarcely possible to decide whether some of those species which are situated on the very boundary belong to the animal or vegetable kingdom.

Not easily distinguished.

To draw a line of distinction, then, between animals and vegetables, would be a very difficult task: but it is not necessary at present to attempt it; for almost the only animals whose bodies have been hitherto examined with any degree of chemical accuracy, belong to the

most perfect classes, and consequently are in no danger of being confounded with plants. Indeed, the greater number of facts which I have to relate apply only to the human body, and to those of a few domestic animals. The task of analysing all animal bodies is immense, and must be the work of ages of indefatigable industry.

This part of the subject naturally divides itself into four Chapters. In the First Chapter, I shall give an account of the different ingredients hitherto found in animals, such of them at least as have been examined with any degree of accuracy: in the Second, I shall treat of the different members of which animal bodies are composed; which must consist each of various combinations of the ingredients described in the First Chapter: in the Third, I shall treat of those animal functions which may be elucidated by chemistry: and, in the Fourth, of the changes which animal bodies undergo after death.

parated, be washed repeatedly in cold water till the quid ceases to be coloured, or to abstract any thing; the skin, thus purified, be put into a quantity of pure ater, and boiled for some time, part of it will be dislved. Let the decoction be slowly evaporated till it is duced to a small quantity, and then put aside to cool. hen cold, it will be found to have assumed a solid rm, and to resemble precisely that tremulous subtance well known to every body under the name of *lly*. This is the substance called in chemistry *gelatine*. the evaporation be still farther continued, by exposing the jelly to dry air, it becomes hard, semitransparent, breaks with a glassy fracture, and is in short the ubstance so much employed in different arts under the ame of *glue*. Gelatine, then, is precisely the same ith glue; only that it must be supposed always free rom those impurities with which glue is so often conaminated.

Properties.

2. Gelatine is semitransparent and colourless when ure. Its consistency and hardness vary considerably. The best kinds are very hard, brittle, and break with a glassy fracture. Its taste is insipid, and it has no mell.

When thrown into water it swells very much, but oes not readily dissolve; and when taken out, it is oft and gelatinous; but when allowed to dry, it reovers its former appearance. If it be put in this getinous state into warm water, it very soon dissolves, nd forms a solution of an opal colour, and the more paque according to the quantity of gelatine which it ontains. Tremulous gelatine dissolves in a very small ortion of hot water; but as the solution cools, it gela- afresh. If this solution, as soon as it assumes

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riatic acid dissolves glue with great ease. The on is of a brown colour, and still continues strong-l. It gradually lets fall a white powder. This n precipitates tan in great abundance from wa-nd may be employed with advantage to detect hen an alkali conceals it. Sulphuric acid acts more slowly. The solution is brown, and gra- deepens; sulphurous acid is exhaled during the of sulphuric acid on glue. Neither sulphuric uriatic acid occasion any change in the solution e in water.

en a current of oxymuriatic acid gas is passed h a solution of gelatine in water, a white solid collects on the surface, and whitish filaments through the liquid. This solid matter, when se-d by the filter and purified, possesses the follow-roperties: Its colour is white; it is specifically r than water; it has little or no taste; when dried open air it falls to powder; it is not soluble in g water; it dissolves in hot nitric and acetic acids, ecipitates again as the solution cools; when tri-d with potash it emits the smell of ammonia; it ot affect vegetable blues *. Bouillon La Grange, om we are indebted for these facts, has given the ne thus altered the name of *oxygenized gelatine*.

Of alkalies and earths.

alies dissolve gelatine with facility, especially assisted by heat; but the solution does not pos-he properties of soap.

ne of the earths seem to combine with gelatine; st they do not precipitate it from its solution in

* Bouillon La Grange, Nicholson's *Jour.* xiii. 209.

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water. The following Table exhibits the effect of different earthy solutions when mixed with a pretty concentrated solution of common glue.

SUBSTANCES.	EFFECTS.
Lime water	No change
Strontian water	No change
Barytes water	Became milky. Precipit. not dissolved by acetic acid
Muriate of barytes	The same as the last
Silicated potash	No change
Aluminated potash	No change
Oxalate of ammonia	Became milky
Phosphate of soda	Became slightly milky

The milkiness produced by some of these reagents was not owing to their effect upon the gelatine, but upon the lime and the sulphuric acid which it contained.

Of the metallic oxides,

The metals in their pure state have no effect upon gelatine; but several of the metallic oxides, when agitated in a solution of gelatine, have the property of depriving the water of the greatest part of that body, with which they form an insoluble compound. Several of the metallic salts likewise precipitate gelatine from water. The following Table exhibits the result of mixing various metallic salts with a concentrated solution of gelatine, as far as my experiments have gone:

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...IC SOLUTIONS.	EFFECTS.
...uriate of gold	A copious yellowish white precipitate. Soluble by adding water
... of silver	Becomes slightly milky
... of mercury	A very copious curdy precipitate
...iate of mercury*	A copious white precipitate
...ysulph. of merc.	No change
...ysulph. of merc.	Cryst. become yellow, white flakes appear, and the liquid becomes transparent
...e of mercury	No change
...ate of copper	No change
... of copper	Becomes milky
...hate of copper	No change
... of ammonia	No change
... of iron †	A few yellow flakes appear
...hate of iron ‡	Becomes slightly milky, as when alcohol is added
...ate of iron	Assumes a pink colour
...iate of iron	Becomes green
...triate of tin §	No change
...iate of tin	Becomes slowly milky

...tock, in his excellent paper on animal fluids, informs us, that ...f one part of isinglass in 100 parts of water is not affected ...ate of mercury. The result of my experiments with com... ...was different; probably owing to the impurity of that sub...

...in the state of oxysulphate. ‡ Dissolved in alcohol.
...xcess of acid.

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METALLIC SOLUTIONS.	EFFECTS.
Nitrate of lead Acetate of lead Plumbate of potash Plumbate of lime	No change
Muriate of zinc	No change
Muriate of antimony Tartar emetic	A copious flaky precipitate No change
Nitrate of bismuth precipitable by water Ditto not precipitable by water	Becomes milky No change
Muriate of arsenic	No change

Of alcohol.

Gelatine is insoluble in alcohol. When alcohol is mixed with a solution of gelatine, the mixture becomes milky; but becomes again transparent when agitated, unless the solution be concentrated, and the quantity of alcohol considerable. Gelatine is most probably equally insoluble in ether; though I believe the experiment has not been tried.

Of tannin.

When the solution of tannin is dropt into gelatine, a copious white precipitate appears, which soon forms an elastic adhesive mass not unlike vegetable gluten. This precipitate is composed of gelatine and tannin; it soon dries in the open air, and forms a brittle resinous-like substance, insoluble in water, capable of resisting the greater number of chemical agents, and not susceptible of putrefaction. It resembles exactly overtanned leather. The precipitate is soluble in the solution of gelatine, as Mr Davy first observed. Neither is the

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ian thrown down, unless the solutions both of
and gelatine be somewhat concentrated. Tremu-
latine, as was first observed by the same chemist,
t precipitate tannin; but if we employ a solu-
gelatine so strong that it gelatinizes when cold,
ted till it becomes quite liquid, it answers best
r throwing down tannin. It is by this property
ing a white precipitate with tannin that gelatine
ly detected in animal fluids. It is not, however,
ctly decisive test, as *albumen* is also thrown
y tannin. Dr Bostock has pointed out a very
us method of detecting and ascertaining the quan-
gelatine contained in an animal fluid. If oxy-
of mercury produce no precipitate, we may be
of the absence of albumen. Then the infusion
being mixed with the liquid, in such a propor-
t the filtered liquid will neither precipitate infu-
galls, or the animal liquid under examination, a
ate falls, composed of about two parts tannin
e parts gelatine. Hence this precipitate dried
am bath, and multiplied by 0·6, gives us the
of gelatine in the liquid examined very nearly *.
tine does not, properly speaking, combine with
t it renders them miscible with water, and forms
of emulsion.

Composition.

rom the effects of different reagents on gelatine,
m the decomposition which it undergoes when

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ock, Nicholson's *Jour.* xiv. 144. From the latter experiments
ock, it appears that the compound of tannin and gelatine differs
portion of its constituents according to circumstances. It does
fore, furnish us with a method of detecting the quantity of ge-
olution. Nicholson's *Jour.* xxi. 1.

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heated, we see that it contains carbon, hydrogen, azote, and oxygen. But what the proportion of these constituents are, cannot be easily ascertained. The phosphate of lime, and the traces of soda, which it always yields, are most likely only held in solution by it.

Species.

5. Gelatine, like all other constituents of animal bodies, is susceptible of numerous shades of variations in its properties; and of course is divisible into an indefinite number of species. Several of these have been long known and manufactured for different purposes: and many curious varieties have been pointed out by Hatchett in his admirable Dissertations on Shell, Bone, and Zoophytes, published in the Philosophical Transactions for 1797 and 1800. The most important species are the following:

Glue.

1. *Glue.* This well-known substance has been long manufactured in most countries, and employed to cement pieces of wood together. It is extracted by water from animal substances, and differs in its qualities according to the substances employed. Bones, muscles, tendons, ligaments, membranes, and skins, all yield it; but the quality is best when skins are employed; and those of old animals yield a much stronger glue than those of young animals. English glue is considered as the best, owing to the care with which it is made. The parings of hides, pelts from furriers, the hoofs and ears of horses, oxen, calves, sheep, &c. are the substances from which it is extracted in Britain, and quantities of these substances are imported for the purpose. They are first digested in lime-water to clean them, then steeped in clean water, laid in a heap till the water runs off, and then boiled in brass caldrons with pure water. The impurities are skimmed off as they rise;

nd when the whole is dissolved, a little alum or finely owdered lime is thrown in. The skimming having een continued for some time, the whole is strained hrough baskets, and allowed to settle. The clear liuid is gently poured back into the kettle, boiled a econd time, and skimmed till it is reduced to the proer consistency. It is then poured into large frames, here it concretes on cooling into a jelly. It is cut by spade into square cakes, which are again cut by means f a wire into thin slices; these slices are put into a ind of coarse net work, and dried in the open air *. The best glue is extremely hard and brittle; it has a ark brown colour, and an equal degree of transpareny without black spots. When put into cold water, it wells very much, and becomes gelatinous, but does not issolve. When glue is soluble in cold water, it is a roof that it wants strength. Dry glue, according to Dr Bostock, contains $10\frac{1}{2}$ *per cent.* of water. He thinks lso that it contains albumen. But from the method of reparing it this can hardly be supposed †.

Size.

2. *Size.* This substance differs from glue in being olourless and more transparent. It is manufactured in he same way, but with more care; eel skins, vellum, archment, some kinds of white leather, and the skins f horses, cats, rabbits, are the substances from which it s procured. It is commonly inferior to glue in strength. t is employed by paper-makers to give strength to hat article, and likewise by linen manufacturers, gilders, polishers, painters, &c. ‡.

* Clennel. See Johnson's *History of Animal Chemistry*, i. 315.
† Nicholson's *Jour.* xxiv. 7.
‡ Clennel. See Johnson's *History of Animal Chemistry*, i. 315.

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Isinglass.

3. *Isinglass.* This substance agrees with size in being transparent, but it is much finer, and is therefore sometimes employed as an article of food. It is prepared in Russia from the air-bladders and sounds of different kinds of fish which occur in the mouths of large rivers; chiefly different species of *accipenser*, as the *sturio stellatus*, *huso ruthenus*, and likewise the *silurus glanis*. The bladder is taken from the fish, clean washed, the exterior membrane separated, cut lengthwise and formed into rolls, and then dried in the open air. When good, isinglass is of a white colour, semitransparent, and dry. It dissolves in water with more difficulty than glue, probably because it is not formed originally by solution. From the analysis of isinglass by Hatchett, we learn that it is almost completely convertible into gelatine by solution and boiling. 500 grains of it left by incineration 1·5 grains of phosphate of soda, mixed with a little phosphate of lime.

A coarse kind of isinglass is prepared from sea wolves, porpoises, sharks, cuttle fish, whales, and all fish without scales. The head, tail, fins, &c. of these are boiled in water, the liquid skimmed and filtered, and then concentrated by evaporation till it gelatinizes on cooling. At that degree of concentration it is cast on flat slabs and cut into tablets. This species is used for clarifying, stiffening silk, making sticking plaster, and other purposes *.

Substances containing it.

6. Gelatine exists in great abundance in animals, forming a constituent part both of their fluid and solid

* Fabricius *de Ichthyocolla*. Jackson on *British Isinglass*, *Phil. Trans.* lxiii. and Johnson's *Animal Chemistry*, i. 231.

parts. Blood and milk yield it always; and it makes its appearance occasionally in the other liquids. It forms an essential part of bones, ligaments, tendons, membranes, skin, muscles, hair, &c.

7. Its uses are very numerous. In the state of jelly it constitutes one of the most nourishing and palatable species of food. It constitutes the basis of soups. The great variety of purposes to which it is applied in the state of glue, size, and isinglass, are well known. Uses.

SECT. II.

OF ALBUMEN.

The eggs of fowls contain two very different substances: a yellow oily-like matter, called the *yolk*; and a colourless glossy viscid liquid, distinguished by the name of *white*. This last is the substance which chemists have agreed to denominate *albumen* *. The white of an egg, however, is not pure albumen. It contains also some mucus, soda, and sulphur: but as albumen is never found perfectly pure, and as no method is known of separating it without at the same time altering the properties of the albumen, chemists are obliged to examine it while in combination with these bodies. Contained in eggs.

* This is merely the Latin term for the white of an egg. It was first introduced into chemistry by the physiologists.

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Albumen dissolves readily in water, and the solution has the property of giving a green colour to vegetable blues, in consequence of the soda which it contains.

Coagulates when heated.

When albumen is heated to the temperature of 165° *, it *coagulates* into a white solid mass; the consistency of which, when other things are equal, depends, in some measure, on the time during which the heat was applied. The coagulated mass has precisely the same weight that it had while fluid. This property of coagulating when heated is characteristic of albumen, and distinguishes it from other bodies.

The taste of coagulated albumen is quite different from that of liquid albumen: its appearance, too, and its properties, are entirely changed; for it is no longer soluble, as before, either in hot or in cold water.

The coagulation of albumen takes place even though air be completely excluded; and even when air is present their is no absorption of it, nor does albumen in coagulating change its volume †. Acids have the property of coagulating albumen, as Scheele ascertained ‡. Alcohol also produces, in some measure, the same effect. *Heat*, then, *acids* and *alcohol*, are the agents which may be employed to coagulate albumen.

It is remarkable, that if albumen be diluted with a sufficient quantity of water, it can no longer be coagulated by any of these agents. Scheele mixed the white of an egg with ten times its weight of water, and then, though he even *boiled* the liquid, no coagulum appeared. Acids, indeed, and alcohol, even then coagulated

* Cullen.
† Carradori, *Ann. de Chim.* xxix. 98.
‡ Scheele, ii. 58.

t.; but they also lose their power if the albumen be diluted with a much greater quantity of water, as has been ascertained by many experiments. Now, when water is poured into albumen, its integrant particles must be farther separated from each other, and their distance must increase with the quantity of water with which they are diluted. We see, therefore, that albumen ceases to coagulate whenever its particles are separated from each other beyond a certain distance. That no other change is produced, appears evident from this circumstance, that whenever the watery solution of albumen is sufficiently concentrated by evaporation, coagulation takes place, upon the application of the proper agents, precisely as formerly.

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It does not appear that the distance of the particles of albumen is changed by coagulation; for coagulated albumen occupies precisely the same sensible space as liquid albumen *.

Inquiry into the cause.

Now, to what is the coagulation of albumen owing? We can conceive no change to take place from a state of liquidity to that of solidity, without some change in the figure of the particles of the body which has undergone that change. Now such a change may take place three ways: 1. The figure may be changed by the addition of some new molecules to each of the molecules of the body. 2. Some molecules may be abstracted from every integrant particle of the body. 3. Or the molecules, of which the integrant particles are composed, may enter into new combinations, and form new integrant particles, whose form is different from that of

* Carradori.

Book V. the old integrant particles. Some one or other of these three things must take place during the coagulation of albumen.

1. Scheele and Fourcroy have ascribed the coagulation of albumen to the first of these causes, namely, to the addition of a new substance. According to Scheele, *caloric* is the substance which is added. Fourcroy, on the contrary, affirms that it is *oxygen*.

Ascribed to caloric;

Scheele supported his opinion with that wonderful ingenuity which shone so eminently in every thing which he did. He mixed together one part of white of egg and four parts of water, added a little pure alkali, and then dropt in as much muriatic acid as was sufficient to saturate the alkali. The albumen coagulated. But when he repeated the experiment, and used carbonate of alkali instead of pure alkali, no coagulation ensued. In the first case, says he, there was a double decomposition: the muriatic acid separated from a quantity of caloric with which it was combined, and united with the alkali; while, at the same instant, the caloric of the acid united with the albumen, and caused it to coagulate. The same combination could not take place when the alkaline carbonate was used, because the carbonic acid gas carried off the caloric, for which it has a strong affinity *.

To oxygen.

Fourcroy observes, in support of his opinion, that the white of an egg is not at first capable of forming a hard coagulum, and that it only acquires that property by exposure to the atmosphere. It is well known that the white of a new laid egg is milky after boiling; and

* Scheele, ii. 58.

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he shell be covered over with grease to exclude ernal air, it continues long in that state; whereas te of an old egg, which has not been preserved manner, forms a very hard tough coagulum. acts are undoubted; and they render it exceedrobable, that albumen acquires the property of a hard coagulum only by absorbing oxygen: y by no means prove that coagulation itself is o such an absorption. And since coagulation lace without the presence of air, and since no n when it is present, is absorbed, this opinion be maintained without inconsistency.

he only substance which can be supposed to bumen during coagulation, since it does not lose ht, is *caloric*. We know that in most cases a fluid is converted into a solid, caloric is actualngaged. It is extremely probable, then, that ne disengagement takes place here. But the has not been confirmed by any proof. Fourdeed says, that in an experiment made by him, rmometer rose a great number of degrees. But ther person has ever been able to observe any ing, it cannot be doubted that this philosopher n misled by some circumstance or other to which not attend *.

The coagulation of albumen resembles exactly kes place when concentrated silicated potash is saturated with muriatic acid. The mass slowly s an opal colour, and at last concretes into a solid ous mass. Now this jelly consists of the particles

* Thomson's *Fourcroy*, iii. 271.

of silica combined with each other, and with a certain portion of water. These particles were formerly held in solution by the potash; that is to say, the affinity of silica for potash was superior to the cohesive force which exists between the particles of silica. The muriatic acid, by saturating the potash, diminished the force of its affinity for the silica. The cohesive force of the silica, now superior, causes it to combine in masses, consisting of a certain portion of silica and water. These masses, equally diffused through the liquid, and at such small intervals as to cohere together, gives the whole a gelatinous form. Something like this seems to take place with respect to the albumen. Its particles, combined with water and also with soda, are all kept at equal distances in the liquid; because this affinity just balances their cohesive force. But when heat is applied, this affinity is diminished by the additional elasticity, or tendency to separate, given to the water and the soda. The cohesion of the albumen, now superior, causes its particles to combine in sets, forming solid bodies, equally distant from each other, and cohering together. Hence the gelatinous form, and the solidity of the coagulum, always inversely proportional to the quantity of water present. Thus it appears, that whatever diminishes the affinity between the water and soda and the albumen, occasions its coagulation, by allowing its cohesive force to act.

Albumen, then, is capable of existing in two states; the one before it has been coagulated, and the other after it has undergone coagulation. Its properties are very different in each. It will be proper therefore to consider them separately.

1. Albumen in its natural state, or uncoagulated, is a

glary liquid, having little taste and no smell. When dried spontaneously, or in a low heat, it becomes a brittle transparent glassy like substance; which, when spread thin upon surfaces, forms a varnish, and is accordingly employed by bookbinders for that purpose. When thus dried it has a considerable resemblance to gum arabic, to which also its taste is similar. The white of an egg loses about $\frac{4}{5}$ths of its weight in drying. It is still soluble in water, and forms the same glary liquid as before.

Chap. I. Uncoagulated albumen.

From the experiments of Dr Bostock, it appears, that when one part of this dry albumen is dissolved in nine parts of water, the solution becomes perfectly solid when coagulated by heat; but if the albumen amounts only to $\frac{1}{15}$th of the liquid, then, though coagulation takes place, the liquid does not become perfectly solid, but may be poured from one vessel to another *.

When one grain of albumen is dissolved in 1000 grains of water, the solution becomes cloudy when heated †.

Its properties.

Uncoagulated albumen soon putrefies unless it be dried; in which state it does not undergo any change. It putrefies more readily when dissolved in a large quantity of water than when concentrated. The smell of white of egg, allowed to run into putrefaction, resembles that of *pus* ‡.

It is insoluble in alcohol and ether, which immediately coagulate it, unless it be mixed with a very great proportion of water; in which case even acids have no effect.

* Nicholson's *Jour.* xiv. 141. † Bostock, Ibid. xi. 247.
‡ Id. Ibid. xiv. 143.

When acids are poured upon it, coagulation takes place equally; but several of them have the property of dissolving it again when assisted by heat. This at least is the case with sulphuric acid. The solution is of a green colour, and does not soon blacken even when boiled. It is the case also with nitric acid, and probably also with muriatic acid. Nitric acid first disengages some azotic gas; then the albumen is gradually dissolved, nitrous gas emitted, oxalic and malic acids formed, and a thick oily matter makes its appearance on the surface *.

I tried the effect of different acids upon a solution consisting of the albumen of a common-sized hen's egg in about a pint of water, and filtered. The results may be seen in the following Table:

ACIDS.	EFFECTS.
1. Sulphuric acid	A white coagulum, which appears at the bottom first
2. Muriatic acid.........	Becomes at once very milky, flakes fall slowly
3. Nitric acid............	A very copious precipitate of yellow flakes soon falls to the bottom, and a slight effervescence is perceptible
4. Oxymuriatic acid ...	Assumes a beautiful white colour, and fine white flakes slowly separate
5. Sulphurous acid......	No change †. Coagulates in 12 hours
6. A weak fluoric acid	No change
7. Acetic acid	No change
8. Distilled vinegar	No change

* Scheele, Crell's *Annals*, ii. 17. Eng. Transl.

† The water was saturated with the acid.

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y be proper to mention, that the solution was ted by alcohol but not by heat.

Of alkalies and earths.

alkalies are mixed with the solution of albu- water, no apparent change takes place; but if a ated solution of pure potash be triturated with for some time, and then allowed to remain at albumen gradually coagulates or rather gela- for the coagulum has a striking resemblance to It gradually hardens; and at a particular period ying it resembles very exactly the lense of the When quite dry it is brittle and transparent.

ffect of the different earthy bodies on the solu- albumen in water may be seen from the fol- Table. The solution consisted of one white of olved in about a pint of water, and filtered to the opaque white films which are always mix- white of egg.

SUBSTANCES.	EFFECTS.
tes water	No change
tian water	No change
water	No change
hate of magnesia	No change
n	No change
ted potash	No change
inated potash	No change

it appears that none of the earths form inso- mpounds with albumen; in this respect they the alkalies.

Of metallic

ase is very different with the metallic oxides. owing Table exhibits the effects of the metallic the same solution of albumen, as far as my ex- s go.

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METALLIC SALTS.	EFFECTS.
1. Nitromuriate of gold	A copious yellow flaky precipitate, redissolved by ammonia *
2. Muriate of platinum	A yellowish-white precipitate
3. Nitrate of silver	A copious reddish-brown precipitate, not redissolved by ammonia
4. Nitrate of mercury	A white precipitate
5. Corrosive sublimate	A light white precipitate
6. Superoxysulph. of do.	A white precipitate
7. Prussiate of do.	No change
8. Oxynitrate of copper	A green coagulum, redissolved by adding more of the copper; then the mixture becomesopaque
9. Muriate of copper	A copious white precipitate
10. Oxysulphate of copper	A greenish-white precipitate
11. Cuprate of ammonia	No change. Muriatic acid renders the mixture colourless, but no precipitate falls
12. Sulphate of iron	Brown flakes precipitate
13. Oxysulphate of ditto in alcohol	A copious dirty white precipitate
14. Oxymuriate of iron	No change
15. Oxynitrate of iron	No precipitate. Becomes green
16. Oxymuriate of tin	Becomes slowly milky

* The salt had a slight excess of acid.

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METALLIC SALTS.	EFFECTS.
17. Hyperoxymuriate of lead	A copious white precipitate
18. Acetate of lead	The same
19. Nitrate of lead	The same
20. Plumbate of potash	No change; but muriatic acid throws down a copious white precipitate
21. Plumbate of lime	No change
22. Muriate of zinc	Becomes slowly very milky
23. Nitrate of bismuth	A white precipitate, which does not appear immediately unless there be an excess of acid
24. Nitrate of antimony	A white precipitate
25. Muriate of arsenic	Becomes slowly milky
26. Arseniate of potash	No change
27. Arseniate of cobalt	No change
28. Prussiate of potash	No change
29. Oxalate of ammonia	A slight white precipitate appears after standing an hour

Thus we see that every metal tried, except cobalt, occasioned a precipitate; but no precipitate ever appeared when the oxide was held in solution by an alkali or earth. The effect of the metallic salts on albumen forms a striking contrast with their effect on gelatine.

From the experiments of Dr Bostock, it appears that a drop of the saturated solution of oxymuriate of mercury, let fall into water containing $\frac{1}{2000}$th part of its

sceptible of decomposition as uncoagulated al- Mr Hatchett kept it for a month under water, it did not become putrid. It is to the experi- f this ingenious chemist that we are indebted st every thing at present known relative to coa- lbumen. By drying it in the temperature of e converted it into a brittle hard yellow sub- emitransparent like horn *.

Chap. I. Its properties.

this substance was digested for some hours in t gradually softened, and became white and ike newly coagulated albumen. When water to act upon it long, a small portion of it is taken e watery liquid is not precipitated by the in- f tan; but nitromuriate of tin occasions a faint

Action of water,

ding to Scheele, the mineral acids, when great- d with water, dissolve a portion of coagulated , which is thrown down again by the same centrated ‡.

Of acids.

coagulated albumen is steeped in diluted ni- the acid in about four weeks begins to acquire tinge, which becomes gradually deeper; but men, though it becomes more opaque, is not l. The yellow acid, when saturated with am- ecomes of a deep orange colour, but does not ny precipitate. When the albumen, thus treat- mersed in ammonia, the liquid assumes a deep lour, inclining to blood red. The albumen is issolved, and the solution has a deep yellowish lour. If the albumen, after being steeped in

Changed into gelatine.

* chett, *Phil. Trans.* 1800.

† Hatchett, Ibid.

‡ eele, ii. 57.

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nitric acid, be washed and then boiled in water, it is dissolved, and forms a pale yellow liquid, which gelatinizes when properly concentrated. If the gelatinous mass be again dissolved in boiling water, the solution is precipitated by tan and by nitro-muriate of tin. Hence we see that nitric acid has the property of converting coagulated albumen into gelatine. For this important fact we are indebted entirely to Mr Hatchett *.

Concentrated nitric acid dissolves coagulated albumen with effervescence, especially when assisted by heat. It becomes orange brown when mixed with ammonia, but no precipitate falls †.

Action of alkalies.

It is readily dissolved by a boiling lixivium of potash, ammonia is disengaged, and an animal soap is formed. This soap, when dissolved in water, and mixed with acetic or muriatic acids, lets fall a precipitate which is of a saponaceous nature. When heated gently some oil flows from it, and a brownish viscid substance remains ‡. The alkalies, when diluted, and not assisted by heat, act upon it slowly and imperfectly.

These properties indicate sufficiently that coagulated albumen is a very different substance from uncoagulated albumen. During the coagulation its component parts must arrange themselves differently.

Composition of albumen.

III. From the effects of nitric acid on albumen; and its products, when subjected to destructive distillation, it has been concluded that it consists of carbon, hydrogen, azote, and oxygen, in unknown proportions. As it yields more azotic gas to nitric acid, it has been considered as containing more of that principle than gela-

* Hatchett, *Phil. Trans.* 1800. † Id. Ibid. ‡ Id. Ibid.

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tine. It is obvious, however, that it does not differ much from that body, as nitric acid spontaneously converts it into gelatine. Mr Hatchett has rendered it very probable that it is the first of the soft parts of animals that is formed, and that all the other soft parts are formed from it.

Species of it.

IV. Like all other animal substances, albumen is capable of existing in various states both when coagulated and uncoagulated, forming a number of distinct species; but they have not been characterized with much precision. But if the curdy part of milk be considered as an albumen, as some chemists do, it constitutes a species essentially distinct from the albumen of eggs and blood. Coagulated albumen forms an essential part of bone and muscle; brain perhaps may be considered as a species of it, and so may the lense of the eye. Cartilage, nails, horns, hair, &c. as Hatchett has shown, are almost entirely composed of it; and it forms the membranous part of many shells, sponges, &c. In short, it is one of the most general and important of the animal substances.

V. The property which albumen has of being coagulated by heat renders it a very useful substance for clarifying liquids. The serum of blood, white of egg, or any liquid containing it, is mixed with the liquid to be clarified, and the whole is then heated. The albumen coagulates, and carries down with it the floating particles which rendered the liquid opaque.

SECT. III.

OF MUCUS.

No word in chemistry has been used with less
sion than *mucus*. Too many experimenters have
it serve as a common name for every animal sub
which cannot be referred to any other class. I
stock, in his excellent Papers on the Analysis of
mal Fluids, has endeavoured to fix the meaning
word by ascertaining the properties of pure
Fourcroy and Vauquelin have lately written an
rate paper on the same subject *.

From Bostock's experiments it appears, that if t
lid matter obtained by evaporating saliva to dryn
redissolved in water and filtered, the solution wil
tain very little except mucus. He obtained
also, by macerating an oyster in water and evapo
the liquid †. Mucus, thus obtained, possesses th
lowing properties:

1. It has much the appearance of gum arabic
cepting that, in general, it is rather more opaque; li
it has little taste, dissolves readily in water, and f
an adhesive solution.

* *Ann. du Mus. d'Hist. Nat.* xii. 61.

† Nicholson's *Jour.* ii.

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2. When evaporated to dryness it is transparent, inelastic, and has much the appearance of gum. It is insoluble in water, but dissolves readily in all the acids though very much diluted.

3. It does not dissolve in alcohol nor in ether.

4. It does not coagulate when heated; nor when concentrated by evaporation does its solution assume the form of a jelly.

5. It is not precipitated by the oxymuriate of mercury, nor by the infusion of galls*.

6. The acetate of lead occasions a copious white precipitate when dropt into solutions containing mucus; the superacetate produces a much less striking effect†.

7. Nitrate of silver likewise occasions a precipitate in solutions containing mucus.

8. When heated it assumes the appearance of horn, and when distilled it yields the common products of animal substances. According to Fourcroy and Vauquelin, horn, nails, hair, feathers, the epidermis, and the scales which form on the skin consist chiefly of mucus.

Many of the substances called *mucus* have the property of absorbing oxygen, and of becoming by that means insoluble in water. They resemble vegetable extractive in this respect.

The mucilaginous substances shall be pointed out in the next Chapter. In the present state of our knowledge, any account of them here would merely be a repetition of the properties just mentioned.

* Bostock, Nicholson's *Jour.* xi. 251. † Ibid. ‡ Ibid.

[illegible] from [illegible] some time, [illegible] Se[illegible] [illegible] muscles of [illegible] washed for a [illegible] substance, [illegible] small pieces, and macer[illegible] changing the water ev[illegible] pressure at the same [illegible] water. As the wea[illegible] putrefaction during [illegible] which amounted

er this treatment it might be considered as fibrin rly as pure as it can be obtained *. Chap. I.

?. Fibrin is of a white colour, has no taste nor smell, is not soluble in water nor in alcohol. When newly racted from blood, it is soft and elastic, and resems very much the gluten of vegetables. Its colour pens very much in drying. That which is extracted n muscle by boiling and maceration has a certain ree of transparency, and is not ductile but brittle. colour does not deepen nearly so much as the fibrin n blood. Properties.

t undergoes no change though kept exposed to the on of air; neither does it alter speedily though kept ered with water. Mr Hatchett kept a quantity of fibrin which he had prepared from beef moistened h water during the whole month of April; it acred a musty but not a putrid smell, neither were the es reduced to a pulpy mass. Even when kept two nths under water, it neither became putrid, nor was verted into the fatty matter obtained by macerating nt muscle †.

When fibrin is exposed to heat, it contracts very denly, and moves like a bit of horn, exhaling at the e time the smell of burning feathers. In a stronger t it melts. When exposed to destructive distillation, ields water, carbonate of ammonia, a thick heavy d oil, traces of acetic acid, carbonic acid, and careted hydrogen gas ‡. The charcoal, as Hatchett asained, is more copious than that left by gelatine or umen. It is very difficult to incinerate, owing to the ence of phosphate of soda and some phosphate of

* Hatchett, *Phil. Trans.* 1800. † Ibid.
‡ Fourcroy, ix. 158.

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lime, which form a glassy coat on the surface. A considerable proportion of carbonate of lime also remains after the incineration of the charcoal *.

Action of acids.

3. Acids dissolve fibrin with considerable facility. Sulphuric acid gives it a deep brown colour; charcoal is precipitated, and acetic acid formed. Muriatic acid dissolves it, and forms with it a green coloured jelly. The acetic, citric, oxalic, and tartaric acids, also dissolve it by the assistance of heat; and the solutions, when concentrated, assume the appearance of jelly. Alkalies precipitate the fibrin from acids in flakes, soluble in hot water, and resembling gelatine in its properties †.

Converted into gelatine.

Diluted nitric acid occasions the separation of a good deal of azotic gas, as was first observed by Berthollet. Mr Hatchett steeped a quantity of fibrin in nitric acid diluted with thrice its weight of water for 15 days. The acid acquired a yellow tinge, and possessed all the properties of the nitric solution of albumen. The fibrin thus treated, dissolved in boiling water, and when concentrated by evaporation, became a gelatinous mass, soluble in hot water, and precipitated by tan and nitro-muriate of tin, and therefore possessing the properties of gelatine. Ammonia dissolves the greater part of the fibrin after it has been altered by nitric acid. The solution is of a deep orange colour, similar to the solution of albumen treated in the same way ‡. Boiling nitric acid dissolves fibrin, except some fatty matter which swims on the surface. The solution resembles that of albumen; except that ammonia throws down a white precipitate, consisting chiefly of oxalate of lime §. Du-

* Hatchett, Fourcroy, ix. 158.
† Fourcroy, ix. 158.
‡ Hatchett, *Phil. Trans.* 1800.
§ Ibid.

Chap. I.

ting the solution, prussic acid comes over, and carbonic acid gas mixed with nitrous gas; a considerable portion of oxalic acid is formed besides the fatty matter which swims *.

From the recent experiments of Fourcroy and Vauquelin on the muscular fibres of animals, there can be little doubt that fibrin, when treated with hot nitric acid, undergoes a suite of changes. 1. It is first converted into a yellow matter, which still possesses the fibrous texture of fibrin. It has the property of converting vegetable blues to red, has a bitter taste, is but little soluble in water, and is insoluble in alcohol. It combines with alkalies, decomposes their carbonates, unites to oils, and gives them rancidity and acid properties. To this substance Fourcroy and Vauquelin have given the name of *yellow acid*. 2. By the farther action of the nitric acid, this yellow matter becomes more soluble, acquires a reddish tinge, and seems to become soluble in alcohol. 3. The last state into which it is brought by nitric acid seems to be that species of *bitter principle* which crystallizes and detonates when combined with ammonia †.

Action of alkalies.

The alkalies, while diluted, have but little effect upon fibrin; but when concentrated potash or soda is boiled upon it, a complete solution is obtained of a deep brown colour possessing the properties of soap. During the solution ammonia is disengaged. When the solution is saturated with muriatic acid, a precipitate is obtained similar to that from animal soap, except that

* Berthollet and Fourcroy, ix. 158.

† Nicholson's *Jour*. xiii. 241.

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it sooner becomes hard and soapy when exposed to the air *.

The earths, as far as is known, have little or no action on fibrin. Neither has the action of the metallic oxides and salts been examined.

Fibrin is insoluble in alcohol, ether, and oils. The effect of other reagents on it has not been examined.

Composition.

4. From the properties above detailed, fibrin appears to be composed of the same constituents as gelatine and albumen; but it probably contains more carbon and azote and less oxygen. The close resemblance which it bears to albumen is very obvious from the experiments of Hatchett just detailed. Nitric acid converts both into *gelatine*, and alkalies convert both into a species of *oil*. Now, as all the soft parts of animals consist of combinations of these three genera, it follows, as Mr Hatchett has observed, that all the soft parts of animals may be either converted into gelatine or animal soap, both substances of the highest importance.

Species.

5. Fibrin exists only in the blood and the muscles of animals: but it is a genus which includes as many species as there are varieties in the muscles of animals; and the great diversity of these substances is well known. The muscles of fish, of fowl, and of quadrupeds, bear scarcely any resemblance to each other.

* Fourcroy, ix. 158. and Hatchett, *Phil. Trans*, 1800.

SECT. V.

OF UREA.

How obtained.

Urea may be obtained by the following process: Evaporate by a gentle heat a quantity of human urine, voided six or eight hours after a meal, till it be reduced to the consistence of a thick syrup. In this state, when put by to cool, it concretes into a crystalline mass. Pour at different times upon this mass four times its weight of alcohol, and apply a gentle heat; a great part of the mass will be dissolved, and there will remain only a number of saline substances. Pour the alcohol solution into a retort, and distil by the heat of a sand-bath till the liquid, after boiling some time, is reduced to the consistence of a thick syrup. The whole of the alcohol is now separated, and what remains in the retort crystallizes as it cools. These crystals consist of the substance known by the name of *urea* *.

Discovery.

It was first described by Rouelle Junior in 1773, under the name of the *saponaceous extract of urine*. He mentioned several of its properties; but very little was known concerning its nature till Fourcroy and Vauquelin published their experiments on it in 1799. These celebrated chemists have given it the name of *urea*, which has been generally adopted.

* Fourcroy and Vauquelin, *Ann. de Chim.* xxxii. 86.

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Properties.

Urea, obtained in this manner, has the form of crystalline plates crossing each other in different directions. Its colour is yellowish white: it has a fetid smell, somewhat resembling that of garlic or arsenic; its taste is strong and acrid, resembling that of ammoniacal salts; it is very viscid and difficult to cut, and has a good deal of resemblance to thick honey *. When exposed to the open air, it very soon attracts moisture, and is converted into a thick brown liquid. It is extremely soluble in water; and during its solution a considerable degree of cold is produced †. Alcohol dissolves it with facility, but scarcely in so large a proportion as water. The alcohol solution yields crystals much more readily on evaporation than the solution in water.

Crystallizes with nitric acid.

When nitric acid is dropt into a concentrated solution of urea in water, a great number of bright pearl-coloured crystals are deposited, composed of urea and nitric acid. No other acid produces this singular effect. The concentrated solution of urea in water is brown, but it becomes yellow when diluted with a large quantity of water. The infusion of nutgalls gives it a yellowish brown colour, but causes no precipitate; neither does the infusion of tan produce any precipitate ‡.

Action of heat.

When heat is applied to urea, it very soon melts, swells up, and evaporates with an insupportably fetid odour. When distilled, there comes over first benzoic acid, then carbonate of ammonia in crystals, some carbureted hydrogen gas, with traces of prussic acid and

* Fourcroy and Vauquelin, *Ann. de Chim.* xxxii. 88.—According to Proust, when obtained by the above processes, the urea is saturated with ammonia.—*Jour. de Phys.* lvi. 113.

† Fourcroy and Vauquelin, *Ann. de Chim.* xxxii. 88. ‡ Ibid.

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there remains behind a large residuum, com-
charcoal, muriate of ammonia, and muriate of
e distillation is accompanied with an almost in-
ly fetid alliaceous odour. Two hundred and
ght parts of urea yield by distillation 200 parts
ate of ammonia, 10 parts of carbureted hydro-
even parts of charcoal, and 68 parts of ben-
, muriate of soda, and muriate of ammonia.
ree last ingredients Fourcroy and Vauquelin
s foreign substances, separated from the urine
cohol at the same time with the urea. Hence
that 100 parts of urea, when distilled, yield

92·027 carbonate of ammonia
4·608 carbureted hydrogen gas
3·225 charcoal

99·860

parts of carbonate of ammonia, according to
and Vauquelin, are composed of 86 ammonia,
ic acid gas, and 24 water. Hence it follows
parts of urea are composed of

39·5 oxygen
32·5 azote
14·7 carbon
13·3 hydrogen

100·0

n scarcely be doubted that the water which
d in the carbonate of ammonia existed ready
n the urea before the distillation *.
the solution of urea in water is kept in a boil-

* *Ann. de Chim.* xxxii. 88.

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ing heat, and new water is added as it evaporates, the urea is gradually decomposed, a very great quantity of carbonate of ammonia is disengaged, and at the same time acetic acid is formed, and some charcoal precipitates *.

Putrefaction.

When a solution of urea in water is left to itself for some time, it is gradually decomposed. A froth collects on its surface; air bubbles are emitted which have a strong disagreeable smell, in which ammonia and acetic acid are distinguishable. The liquid contains a quantity of acetic acid. The decomposition is much more rapid if a little gelatine be added to the solution. In that case more ammonia is disengaged, and the proportion of acetic acid is not so great †.

Action of sulphuric acid,

When the solution of urea is mixed with one-fourth of its weight of diluted sulphuric acid, no effervescence takes place; but, on the application of heat, a quantity of oil appears on the surface, which concretes upon cooling; the liquid which comes over into the receiver contains acetic acid, and a quantity of sulphate of ammonia remains in the retort dissolved in the undistilled mass. By repeated distillations, the whole of the urea is converted into acetic acid and ammonia ‡.

Nitric acid,

When nitric acid is poured upon crystallized urea, a violent effervescence takes place, the mixture frothes, assumes the form of a dark red liquid, great quantities of nitrous gas, azotic gas, and carbonic acid gas, are disengaged. When the effervescence is over, there remains only a concrete white matter, with some drops of reddish liquid. When heat is applied to this residuum

* *Ann. de Chim.* xxxii. 96. † Ibid. ‡ Ibid. p. 104.

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nates like nitrate of ammonia. Into a solution of formed by its attracting moisture from the atmo-, an equal quantity of nitric acid, of the specific r 1·460, diluted with twice its weight of water, ded; a gentle effervescence ensued: a very small as applied, which supported the effervescence or ys. There was disengaged the first day a great y of azotic gas and carbonic acid gas; the second arbonic acid gas, and at last nitrous gas. At the ime with the nitrous gas the smell of the oxy- acid of Berthollet was perceptible. At the end second day, the matter in the retort, which was e thick, took fire, and burnt with a violent ex- ı. The residuum contained traces of prussic acid nmonia. The receiver contained a yellowish quor, on the surface of which some drops of oil *.

Muriatic and oxymuriatic acid.

riatic acid dissolves urea, but does not alter it. uriatic acid gas is absorbed very rapidly by a l solution of urea; small whitish flakes appear, soon become brown, and adhere to the sides of ssel like a concrete oil. After a considerable ty of oxymuriatic acid had been absorbed, the so- left to itself, continued to effervesce exceeding , and to emit carbonic acid and azotic gas. After ervescence was over, the liquid contained muriate bonate of ammonia.

Action of alkalies.

a is dissolved very rapidly by a solution of potash ı, and at the same time a quantity of ammonia is aged; the same substance is disengaged when

* *Ann. de Chim.* xxxii. 107.

Book II.

urea is treated with barytes, lime, or even magnesia. Hence it is evident, that this appearance must be ascribed to the muriate of ammonia, with which it is constantly mixed. When pure solid potash is triturated with urea, heat is produced, a great quantity of ammonia is disengaged; the mixture becomes brown, and a substance is deposited, having the appearance of an empyreumatic oil. One part of urea and two of potash, dissolved in four times its weight of water, when distilled, gives out a great quantity of ammoniacal water; the residuum contains acetate and carbonate of potash*.

When muriate of soda is dissolved in a solution of urea in water, it is obtained by evaporation, not in cubic crystals, its usual form, but in regular octahedrons. Muriate of ammonia, on the contrary, which crystallizes naturally in octahedrons, is converted into cubes, by dissolving and crystallizing it in the solution of urea.

Such are the properties of this singular substance, as far as they have been ascertained by the experiments of Fourcroy and Vauquelin. It differs from all animal substances hitherto examined, in the great proportion of azote which enters into its composition, and in the facility with which it is decomposed, even by the heat of boiling water.

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* *Ann. de Chim.* xxxii. 107.

SECT. VI.

OF SACCHARINE MATTER.

AR has never been found in animals in every re- similar to the sugar of vegetables; but there are n animal substances which have so many proper- n common with sugar, that they can scarcely be ged under any other name. These substances are,

1. Sugar of milk
2. Honey
3. Sugar of diabetic urine.

How obtained.

Sugar of milk may be obtained by the following ss: Let fresh whey be evaporated to the consist- of honey, and then allowed to cool; it concretes solid mass. Dissolve this mass in water, clarify h the white of eggs, filter and evaporate to the stence of a syrup; it deposites on cooling a num- f brilliant white cubic crystals, which are *sugar of* Fabricius Bartholdi, an Italian, was the first Eu- n who mentioned this sugar. He described it in *Encyclopædia Hermetico-Dogmatica*, published at ogna in 1619; but it seems to have been known dia long before that period. For the best account properties we are indebted to Mr Lichtenstein.

Properties.

hen pure it has a white colour, a sweetish taste, o smell. Its crystals are semitransparent regular lelopipeds, terminated by four-sided pyramids. Its fic gravity, at the temperature of 55°, is 1·543.

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At that temperature it is soluble in seven times its weight of water; but is perfectly insoluble in alcohol. When burnt it emits the odour of caromel, and exhibits precisely the appearance of burning sugar. When distilled, it yields the same products as sugar, only the empyreumatic oil obtained has the odour of benzoic acid *. When treated with nitric acid it yields *saclactic* acid. From these experiments, it appears that sugar of milk is specifically different from every kind of vegetable sugar at present known †.

Honey.

2. Honey is prepared by bees, and perhaps rather belongs to the vegetable than the animal kingdom. It has a white or yellowish colour, a soft and grained consistence, a saccharine and aromatic smell. By distillation it affords an acid phlegm and an oil, and its coal is light and spongy like that of the mucilages of plants. Nitric acid extracts from it oxalic acid, precisely as it does from sugar. It is very soluble in water, with which it forms a syrup, and like sugar passes to the vinous fermentation. Mr Cavezzali has lately affirmed that honey is composed of sugar, mucilage, and an acid. The sugar may be separated by melting the honey, adding carbonate of lime in powder as long as any effervescence appears, and scumming the solution while hot. The liquid thus treated gradually deposites cry-

* Scheele, ii. 70.

† If the reader wishes a more detailed account of sugar of milk, he may consult Lichtenstein's *Abhandlung*, published separately in 1772, and Rouelle's dissertation in the 39th volume of the *Jour. de Medicine*. An abridged view of the whole has been given by Morveau in the 1st volume of the *Encycl. Methodique*, which has been published in an English dress by Mr Johnson in his *History of Animal Chemistry*, i. 128.

stals of sugar when allowed to remain in a glass vessel *.

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According to Proust, there are two kinds of honey; one always liquid, and the other solid and not deliquescent. They may be separated, he says, by means of alcohol †.

Sugar of diabetic urine.

3. The urine of persons labouring under the disease known to physicians by the name of *diabetes*, yields, when evaporated, a considerable quantity of matter which possesses properties analogous to sugar. This seems to have been first observed by Willis. Afterwards the subject was carried somewhat farther by subsequent physicians. But it is to Mr Cruikshanks that we are indebted for the most valuable set of experiments on the subject. In this case he extracted from urine about $\frac{1}{11}$th of its weight of a sweet-tasted extract like honey. When treated with nitric acid, it yielded the same proportion of oxalic acid as an equal quantity of common sugar would have done, making allowance for the saline substances present. No saclactic acid was formed. Hence it follows that this substance is not analogous to sugar of milk, but nearer common sugar in its properties. It has been supposed incapable of crystallizing regularly like common sugar. But I have seen it prepared by Dr Wollaston in small grains having almost exactly the appearance of common white sugar. Nicolas affirms that when treated with lime it is decomposed ‡. If so, it certainly differs essentially from common sugar, which Cruikshanks first proved to be capable of uniting to lime without decomposition.

* *Ann. de Chim.* xxxix. 110.

† *Jour. de Phys.* lix. 428.

‡ *Ann. de Chim.* xliv. 64.

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4. Thenard has lately detected a peculiar matter in bile, which he considers as saccharine. I shall give an account of its properties when treating of that animal fluid.

SECT. VII.

OF OILS.

The oily substances found in animals belong all to the class of fixed oils. They differ very much in their consistence, being found in every intermediate state from spermaceti, which is perfectly solid, to train oil, which is completely liquid. The most important of them are the following:

Spermaceti.

1. *Spermaceti.*—This peculiar oily substance is found in the cranium of the *physeter macrocephalus*, or spermaceti whale. It is obtained also from some other species. At first it is mixed with some liquid oil, which is separated by means of a woollen bag. The last portions are removed by an alkaline ley, and the spermaceti is afterwards purified by fusion. Thus obtained it is a beautiful white substance, usually in small scales, very brittle, has scarcely any taste, and but little smell. It is distinguished from all other fatty bodies by the crystalline appearance which it always assumes. It melts, according to the experiments of Bostock, at the temperature of 112°*. When sufficiently heated it may

Properties.

* Nicholson's *Jour.* iv. 134.

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be distilled over without much alteration; but when distilled repeatedly it loses its solid form and becomes a liquid oil *. From the experiments of Thouvenel and Crell, we learn that by repeated distillation it is partly decomposed, and a brown acid liquid obtained. It is soluble in boiling alcohol, but separates again as the solution cools. About 150 parts of alcohol are necessary to dissolve it †. Ether dissolves it cold, and very rapidly when hot; on cooling the whole concretes into a solid mass ‡. It dissolves also in hot oil of turpentine, but precipitates again as the liquid cools §.

The acids have scarcely any action on it; but it unites readily with the pure alkalies, as was shown long ago by Crell, and the fact has been lately confirmed by Dr Bostock. With hot ammonia it forms an emulsion which is not decomposed by cooling nor by water; but the spermaceti is immediately thrown down by the addition of an acid ||. It dissolves sulphur, and is dissolved by the fixed oils. When long exposed to the air it becomes yellow and rancid. This substance is employed like wax and tallow for making candles. It is said also, that if bits of caoutchouc be thrown into it while melted, they are dissolved, and form a compound which answers remarkably well for luting vessels ¶.

Fat.

2. *Fat*.—This substance is found abundantly in different parts of animals. When pure it possesses the properties of the fixed oils. Its consistence varies from

* Neumann.

† Fourcroy and Bostock, Nicholson's *Jour*. iv. 134.

‡ Bostock, Ibid. § Id. Ibid. || Id. Ibid

¶ Nicholson's 4to *Jour*. i. 472.

tallow or suet, which is brittle, to *hog's lard*, whi soft and semifluid. To obtain fat pure, it is c small pieces, well washed in water, and the men nous parts and vessels separated. It is then melt a shallow vessel along with some water, and kept ed till the water is completely evaporated. Th rified it is white, tasteless, and nearly insipid.

Properties. Different kinds of it liquefy at different temper Lard melts at 97°; but the fat extracted from boiling requires, according to Nicholson, a heat of When heated to about 400°, it begins to emit smoke, which becomes more copious and more greeable as the heat increases; at the same time comes blackish, owing doubtless to the decomposi a portion of it and the evolution of some char it be now cooled it becomes more brittle and soli at first. When hog's lard is distilled in a we obtain first a portion of water, and then a whi which concretes in the receiver into small bules; and a black mass remains in the retort. the whole process abundance of carbureted hy and carbonic acid come over, which have a most minable odour. When the vessels are unluted, emit an odour so detestable and powerful that it solutely impossible to endure it. It was formerly posed that this odour was exhaled by the sebacic formed during the process; but Thenard has this to be a mistake. We must therefore ascribe an empyreumatic oil. The smell does not sudd disappear. During this distillation acetic acid is engaged, and likewise some sebacic acid, which is in solution in the receiver mixed with the oil.

These products demonstrate the peculiar natu

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Train oil.

3. *Train oil.*—This liquid is extracted from the blubber of the whale, and from other fish. It forms a very important article of commerce, being employed for combustion in lamps, and for other purposes. It is at first thick; but on standing, a white mucilaginous matter is deposited, and the oil becomes transparent. It is then of a reddish brown colour, and has a disagreeable smell. If it be agitated with a little sulphuric acid, and then mixed with water, the oil, when allowed to settle, swims on the surface, of a much lighter colour than before, the water continues milky, and a curdy matter is observed swimming between the oil and water. This method has been employed for purifying the oil, to make it more proper for burning in lamps. Various other methods have been employed. The most important are those recommended by Mr Dossie *.

Spermaceti oil.

4. *Spermaceti oil.*—This is the oil which separates from spermaceti during the purification of it. It is much purer than train oil, and therefore answers better for burning in lamps.

Butter.

5. *Butter* possesses all the characters of a fixed oil; but as it is not found ready formed in any animal substance, the detail of its properties belongs to the next Chapter.

Oil of ants.

6. *Oil of ants.*—Margraff obtained this oil by macerating the *formica rufa* in water, and distilling off one-half of the liquid. The oil was found swimming upon the surface of the water in the receiver. It is liquid, and dissolves completely in alcohol. Its taste is

* See *Phil. Mag.* xv. 105; and the *Transactions of the Society for the Encouragement of the Arts*, vol. xx.

Chap. I.

not hot, but it has a peculiar smell. It appears to be intermediate between fixed and volatile oils in its properties *.

Animal oil of Dippel.

7. Though all the oily bodies found in animal substances belong to the class of fixed oils, yet there is a peculiar volatile oil which makes its appearance, and which is doubtless formed during the distillation of different animal bodies. Though this oil has now lost that celebrity which drew the attention of the older chemists to it, yet as its properties are peculiar, a short account of it will not be improper. It is usually called the *animal oil of Dippel*, because that chemist first drew the attention of chemists to it. It is usually obtained from the gelatinous and albuminous parts of animals. The horns are said to answer best. The product of the first distillation is to be mixed with water, and distilled with a moderate heat: the oil which is first obtained is the animal oil of Dippel.

It is colourless and transparent; its smell is strong and rather aromatic; it is almost as light and as volatile as ether; water dissolves a portion of it; and it changes syrup of violets green, owing, as is supposed, to its containing a little ammonia. The acids all dissolve it, and form with it a kind of imperfect soap. Nitrous acid sets it on fire. It forms with alkalies a soap. Alcohol, ether, and oils unite with it. When exposed to the air it becomes brown, and loses its transparency. It was formerly used as a specific in fevers †.

* Margraff, *Opusc.* i. 291.

† See the experiments of Model and Dehne.

SECT. VIII.

OF ANIMAL RESINS.

Substances resembling resins are found in different animal bodies; and which, for that reason, may be called *animal resins*. Their properties are somewhat different from the vegetable resins, but they have not been all examined with precision. The following are the most remarkable of these substances.

Resin of bile.

1. *Resin of bile.*—This substance may be obtained by the following process: Into 32 parts of fresh ox bile pour one part of concentrated muriatic acid. After the mixture has stood for some hours, pass it through a filter, in order to separate a white coagulated substance. Pour the filtrated liquor, which has a fine green colour, into a glass vessel, and evaporate it by a moderate heat. When it has arrived at a certain degree of concentration, a green-coloured substance precipitates. Decant off the clear liquid, and wash the precipitate in a small quantity of pure water. This precipitate is the *basis of bile*, or the *resin of bile*, as it is sometimes called *.

Properties.

The resin of bile is of a dark brown colour; but when spread out upon paper or on wood, it is a fine grass green: its taste is intensely bitter †.

When heated to about 122° it melts; and if the heat

* Cadet, *Mem. Par.* 1767, p. 340. † Ibid. p. 341.

be still farther increased it takes fire and burns with rapidity. It is soluble in water, both cold and hot, and still more soluble in alcohol; but water precipitates it from that liquid *. Chap. I.

It is soluble also in alkalies, and forms with them a compound which has been compared to a soap. Acids, when sufficiently diluted, precipitate it both from water and alkalies without any change; but if they be concentrated, the precipitate is redissolved †.

From these properties, it is clear that the resin of bile has a considerable resemblance to vegetable resins; but it differs from them entirely in several of its properties. The addition of oxygen, with which it combines readily, alters it somewhat, and brings it nearer to the class of oils.

In this altered state the resin of bile may be obtained by the following process: Pour oxymuriatic acid cautiously into bile till that liquid loses its green colour; then pass it through a filter to separate some albumen which coagulates. Pour more oxymuriatic acid into the filtered liquid, and allow the mixture to repose for some time. The oxymuriatic acid is gradually converted into common muriatic acid; and in the mean time the basis of bile absorbs oxygen, and acquires new properties. Pour into the liquid, after it has remained a sufficient time, a little common muriatic acid; a white precipitate immediately appears, which may be separated from the fluid. This precipitate is the basis of bile combined with oxygen.

It has the colour and the consistence of tallow, but

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* Fourcroy, *Ann. de Chim.* vii. 178. † Cadet and Maclurg.

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still retains its bitter taste. It melts at the temperature of 104°. It dissolves readily in alcohol, and even in water, provided it be assisted by heat. Acids precipitate it from these solutions *.

The resinous substance discovered by Proust in humane urine does not seem to differ much from the resin of bile. Ear-wax also, from the experiments of Vauquelin, contains a resin which possesses the same properties.

Ambergris.

2. *Ambergris.*—This substance is found floating on the sea, near the coasts of India, Africa, and Brazil, usually in small pieces, but sometimes in masses of 50 or 100 pounds weight. Various opinions have been entertained concerning its origin. Some affirmed that it was the concrete juice of a tree †; others thought it a bitumen; but it is now considered as pretty well established, that it is a concretion formed in the stomach or intestines of the *physeter macrocephalus*, or spermaceti whale ‡.

Properties.

Ambergris when pure is a light soft substance which swims on water. Its specific gravity varies from 0·78 to 0·92, according to Brisson; Bouillon La Grange, who has lately published an analysis of it, found its specific gravity from 0·849 to 0·844 §. Its colour is ash grey, with brownish yellow and white streaks. It has an agreeable smell, which improves by keeping. Its taste is insipid.

When heated to 122° it melts without frothing; if

* Fourcroy, *Ann. de Chim.* vii. 176.

† See the New Abridgement of the *Phil. Trans.* ii. 89.

‡ See *Phil. Trans.* vols. xxxiii. xxxviii. and xc.

§ *Ann. de Chim.* xlvii. 73.

Chap. I.

ıeat be increased to 212°, it is volatilized com-
ly in a white smoke, leaving only a trace of char-
. When distilled, we obtain a whitish acid liquid
a light volatile oil; a bulky charcoal remains be-
*.

is insoluble in water. Acids have little action on
Weak sulphuric acid occasions no change; but
n concentrated it developes a little charcoal. Ni-
acid dissolves it, giving out at the same time nitrous
carbonic acid, and azotic gas. A brownish liquid
rmed, which leaves, when evaporated to dryness,
ittle brown substance, possessing the properties of
sin. The alkalies dissolve it by the assistance of
, and form a soap soluble in water. Both the fixed
volatile oils dissolve ambergris. It is soluble also
her and alcohol †.

Analysis.

/hen 100 parts of ambergris are macerated for
ıty-four hours in 16 parts of alcohol, the liquid
mes a deep yellow colour. By repeating the
ess, the alcohol takes up the whole that is so-
e. Hot alcohol dissolves the rest, except a little
ry matter easily separated by filtration. It weighs
parts. The cold infusions of alcohol being evapora-
to dryness, there remains a brown brilliant sub-
ce, which is readily melted by heat, and which vo-
izes completely when put upon hot charcoal. This
tance possesses the properties of a resin. It a-
nts to 30·8 parts. It is precipitated from alcohol
vater, leaving a portion of benzoic acid, which may
ikewise separated from ambergris by heat, and by

Bouillon La Grange, *Ann. de Chim.* xlvii. 73. † Ibid. 75.

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the usual process by which it is extracted from benzoin. It amounts to 11·1 parts. When the hot alcohol infusion is allowed to cool, it lets fall the portion of ambergris which it held in solution. This substance is of a pale yellow colour, and easily softens by heat. When slowly cooled, it assumes a lamellar form. It possesses the properties of the fatty matter into which the muscles are converted by nitric acid, and which makes its appearance when dead bodies are allowed to putrefy in great numbers together. This substance has been distinguished by the name of *adipocire*, from its resemblance both to fat and wax. The quantity of it in ambergris amounts to 52·8 parts. Such is the analysis of ambergris made by Bouillon La Grange. This substance, then, according to that chemist, is composed

Constituents.

of..................	52·7 adipocire
	30·8 resin
	11·1 benzoic acid
	5·4 charcoal
	100·0 *

Propolis.

3. *Propolis*. This is a substance collected by bees newly placed in a hive. They employ it to cover the bottom of the hive, and to coat over all foreign substances which are too heavy to be removed. The bees bring it on their legs and feet; to which it adheres so strongly that the insect cannot extricate itself; but its associates pull it off with their jaws, and apply it to immediate use. It is probably a vegetable production; but as this is not known for certain, and as it is prepared by animals, I have reserved an account of its pro-

* *Ann. de Chim.* xl

perties for this place. Vauquelin has lately subjected it to a chemical analysis. Chap. I.

It is at first soft and ductile, but it gradually hardens and becomes solid. In large masses it appears blackish; but in thin pieces it is semitransparent. The heat of the fingers is sufficient to soften it, and give it the ductility of wax; but it is more ropy and tenacious. It is tasteless, but has an aromatic odour similar to that of balsam of Peru. When macerated in alcohol, it tinges the liquid of a deep red colour; and by repeating the maceration, the portion soluble is separated. Boiling alcohol dissolved another portion of it; and by repeated decoctions 100 parts of propolis were reduced to 14, which consisted of extraneous bodies. All the alcoholic solutions were mixed and passed through a fine strainer, which separated the portion that precipitated as the decoction cooled. This substance, when properly dried, possessed the properties of wax. The alcohol was now concentrated by distillation, then mixed with water, and boiled. A resinous mass was obtained of a d brown colour, semitransparent, and very brittle. It eighed 57 parts. The water in which it had been iled contained an acid, probably the benzoic. By dis-ation the resinous matter yielded a volatile oil, and ame harder. This resin is soluble in fixed and vo-e oils, and very similar in its properties to the re- of balsam of Peru. Thus 100 parts of propolis ain Properties.

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Constituents.

57 resin
14 wax
14 impurities
15 acid and loss

100 *

Castor.

4. *Castor.* This substance is obtained from the beaver. In each of the inguinal regions of that animal there are two bags, a large and a small. The large one contains the true castor; the small one a substance which has some resemblance to it, but which is in much less estimation. We are indebted to Bouillon La Grange for a set of experiments on it †.

Properties.

Castor is of a yellow colour; and when newly taken from the animal it is nearly fluid. But by exposure to the atmosphere it gradually hardens, becomes darker coloured, and assumes a resinous appearance. Its taste is bitter and acrid, and its odour strong and aromatic. In water it softens, and tinges the liquid of a pale yellow colour. The infusion gives a green colour to vegetable blues, and contains an alkali. By long continued maceration a deeper coloured infusion is obtained, which yields a dry extract of a tortoise shell colour, soluble in ether and alcohol. Water precipitates a resinous substance from the alcohol. From the analysis of Bouillon La Grange, we learn that castor contains the following ingredients:

Constituents.

1. Carbonate of potash
2. Carbonate of lime
3. Carbonate of ammonia

* Nicholson's *Jour.* v. 48. † *Jour. de Phys.* xlii. 65.

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4. Iron
5. Resin
6. A mucilaginous extractive matter
7. A volatile oil

The properties of the resin are analogous to those of the resin of bile.

5. *Civet.*—This substance, like the last, is obtained from the inguinal region of the *civet cat*. It is squeezed out of the cavity where it is secreted every other day. It is employed as a perfume, but has not hitherto engaged the attention of chemists. Its colour is yellow; its consistence that of butter; its smell so strong as to be agreeable only when much reduced by mixture with other bodies. It unites readily with oils, but is said not to dissolve in alcohol. In that case it ought to be excluded from the class of resinous bodies.

6. *Musk*—This substance is secreted into a kind of bag situated in the umbilical region of the quadruped called *moschus moschifer*. Its colour is brownish red; it feels unctuous; its taste bitter; and its smell aromatic and intensely strong. It is partially soluble in water, which acquires its smell; and in alcohol, but that liquid does not retain the odour of musk. Nitric and sulphuric acids dissolve it, but destroy the odour. Fixed alkalies develope the odour of ammonia. Oils do not act on it. At a red heat it has the same fetid smell as urine *. Its component parts have not been ascertained.

7. The *formica rufa*, or red ant, contains also a peculiar resin, as has been proved by Fourcroy and Vauquelin †.

* Neumann.

† *Phil. Mag.* xv. 148.

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SECT. IX.

OF SULPHUR AND PHOSPHORUS.

These two simple combustibles constitute a part of many animal substances; but in what state of combination they exist in them has not been ascertained. All that can be done therefore at present is to mention some of the bodies from which they may be separated.

Sulphur.

1. Sulphur seems to be a never-failing attendant on albumen, in whatever part of the body that substance exists as a constituent. Scheele ascertained its presence in the white of an egg and in milk *; Parmentier and Deyeux in the blood †; Proust in urine and fæces, in the muscles, in hair, &c. and he has made it probable that sulphur is mixed with the matter which is transpired from the body ‡. This chemist informs us, that in the blood it is combined with ammonia in the state of hydrosulphuret of ammonia; but whether it be in the same state in other parts of the body is not known.

Phosphorus.

2. Phosphorus exhales from different animal bodies during putrefaction in the state of phosphureted hydrogen gas, and of course must have been a constituent part of these bodies. The luminous appearance which

* Scheele, ii. 57. † *Jour. de Phys.* xliv. 437.
‡ *Ann. de Chim.* xxxvi. 258.

ne animals exhibit seems, in several instances, to be ing to the presence of this very combustible sub- nce: But the experiments hitherto made upon these mals are not sufficiently decisive. Chap. I.

SECT. X.

OF ACIDS.

HE acids which have been discovered ready formed, l constituting a part of animal bodies, are the fol- ing: Acids.

1. Phosphoric	7. Rosacic
2. Sulphuric	8. Amniotic
3. Muriatic	9. Oxalic
4. Carbonic	10. Formic
5. Benzoic	11. Acetic
6. Uric	12. Malic.

. The phosphoric acid is by far the most abundant ll the acids found in animals. Combined with lime, onstitutes the basis of bone; and the phosphate of e is found in the muscles, and almost all the solid ts of animals; neither are there many of the fluids m which it is absent. In the blood, phosphoric acid ound combined with oxide of iron; and in the urine xists in excess, holding phosphate of lime in solution. Phosphoric.

. Sulphuric acid can scarcely be considered as a ponent part of any of the substances belonging to human body. It is said, indeed, to occur some- Sulphuric.

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times in urine combined with soda. It is, however, a very common constituent of the liquid contents of the inferior animals. Thus sulphate of soda is found in the liquor of the amnios of cows, and sulphate of lime occurs usually in the urine of quadrupeds.

Muriatic.

3. Muriatic acid occurs in most of the fluid animal substances, and is almost always combined with soda, constituting common salt.

Carbonic.

4. Carbonic acid has been detected in fresh human urine by Proust, and it occurs in the urine of horses and cows abundantly, partly combined with lime.

Benzoic.

5. Benzoic acid was first discovered in human urine by Scheele; and Fourcroy and Vauquelin have found it abundantly in the urine of cows. Proust has detected it in the blood, the albumen of an egg, in glue, silk, and wool, in the sponge, different species of algæ, and even in mushrooms. This chemist even thinks it probable that it is a constituent of all substances which contain azote *. Or more probably it is formed during the action of reagents on these substances.

Uric.

6. Uric or lithic acid was discovered by Scheele in 1776. It is the most common constituent of urinary calculi, and exists also in human urine. That species of calculus which resembles wood in its colour and appearance is composed entirely of this substance. It was called at first lithic acid; but this name, in consequence of the remarks made by Dr Pearson on its impropriety, has been laid aside, and that of *uric* acid substituted in its place †.

* *Ann. de Chim.* xxxvi. 272.

† Dr Pearson rather [illegible] to call it [illegible].

Chap. I.

Rosacic.

7. Rosacic. During intermittent fevers urine deposites a very copious precipitate, which has been long known to physicians under the name of *lateritious sediment*. This sediment always makes its appearance at the crisis of fevers. In gouty people, the same sediment appears in equal abundance towards the end of a paroxysm of the disease; and if this sediment suddenly disappears after it has begun to be deposited, a fresh attack may be expected *. Scheele considered this sediment as uric acid mixed with some phosphate of lime; and the same opinion has been entertained by other chemists: but Proust affirms that it consists chiefly of a different substance, to which he has given the name of *rosacic* acid from its colour, mixed with a certain proportion of uric acid and phosphate of lime. This rosacic acid, he informs us, is distinguished from the uric by the facility with which it dissolves in hot water, the violet precipitate which it occasions in muriate of gold, and by the little tendency which it has to crystallize †.

Amniotic.

8. Amniotic acid has been lately discovered by Vauquelin and Buniva in the liquor of the amnios of the cow, and may be obtained in white crystals by evaporating that liquid slowly. Hence they have given it the name of *amniotic acid*. It is of a white and brilliant colour; its taste has a very slight degree of sourness; it reddens the tincture of turnsole; it is scarcely soluble in cold water, but very readily in hot water, from which it separates in long needles as the solution cools. It is soluble also in alcohol, especially when assisted by heat.

* Cruickshanks, *Phil. Mag.* ii. 249. † *Ann. de Chim.* xxxvi. 265.

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It combines readily with pure alkalies, and forms a substance which is very soluble in water. The other acids decompose this compound; and the acid of the liquor of the amnios is precipitated in a white crystalline powder. This acid does not decompose the alkaline carbonates at the temperature of the atmosphere, but it does so when assisted by heat. It does not alter solutions of silver, lead, or mercury, in nitric acid. When exposed to a strong heat it froths, and exhales an odour of ammonia and of prussic acid. These properties are sufficient to show that it is different from every other acid. It approaches nearest to the saclactic and the uric acids; but the first of these does not furnish ammonia by distillation like the amniotic; The uric acid is not so soluble in hot water as the amniotic; it does not crystallize in white brilliant needles, and it is insoluble in boiling alcohol: in both which respects it differs completely from amniotic acid*.

Oxalic. 9. Oxalic acid has hitherto been found only in a few urinary calculi by Vauquelin and Fourcroy.

10. Formic acid has been hitherto found only in the *formica rufa*, or red ant. The details have been already given in a preceding part of this Work.

Acetic. 11. Acetic. This acid has been detected in urine by Proust. It exists also in the *formica rufa*, or red ant, as has been demonstrated by the experiments of Fourcroy and Vauquelin. It appears also, from the labours of these philosophers and of Thenard, that the acid found in milk is the acetic, disguised a little by holding some salts in solution.

* *Ann. de Chim.* xxxiii. 279.

12. Malic acid. This acid has been lately detected by Fourcroy and Vauquelin in the acid liquid obtained from the *formica rufa*. When this liquid is saturated with lime, if acetate of lead be dropt into the solution, a copious precipitate falls, which is soluble in acetic acid. Fourcroy and Vauquelin exposed the precipitate to the proper trials, and ascertained that it was malate of lead.

Chap. I.

Malic.

Other acids.

Besides the acids enumerated above, several others have been mentioned by chemical writers. The truth is, that a variety of acid liquors have been observed in animals; but as these have not been examined, we do not know whether they are peculiar substances, or merely some of those already enumerated. Chaussier, in 1781, pointed out an acid in the silk worm, which has been called *bombic acid**. But the list of its properties which he has given is altogether insufficient to constitute it a peculiar substance; and all subsequent accounts of it which I have seen are mere repetitions of the original paper. Dehne obtained an acid from the insects called *meloe proscarabæus* and *majalis*. Chaussier obtained an acid from the grasshopper and the bug. In short, acids are obtained from many of the insect tribe; and from the experiments published, it is extremely probable that in most of these insects the acid is the acetic.

* *Mem. Dijon*, 1783, ii. 70.

SECT. XI.

OF ALKALIES, EARTHS, AND METALS.

I. All the alkalies have been found in the fluids of animals.

Potash. 1. Potash is rather uncommon in the human fluids; but it has been detected in the milk of cows, and it has been found abundantly in the urine of quadrupeds.

Soda. 2. Soda exists in all the fluids, and seems always to be combined with albumen. Phosphate and muriate of soda are also found. It is this alkali which gives animal fluids the property of tinging vegetable blues green.

Ammonia. 3. Ammonia has been detected by Proust in urine; and it is formed in abundance during the putrefaction of most animal bodies.

II. The only earths hitherto found in animals are lime, magnesia, and silica.

Lime. 1. Lime exists in great abundance in all the larger animals. Combined with phosphoric acid, it constitutes the basis of bones, while shells are composed of carbonate of lime. Phosphate of lime is found also in the muscles and other solid parts, and it is held in solution by almost all the fluids.

Magnesia. 2. Magnesia has been detected in human urine by Fourcroy and Vauquelin, combined with phosphoric

acid and ammonia. It constitutes also sometimes a component part of the urinary calculi.

Silica.

3. Silica has not hitherto been detected in any of the component parts of animals, except hair; but Fourcroy and Vauquelin found it in urinary calculi.

III. The metals found in animals are two; namely, iron and manganese.

Iron.

1. Iron combined with phosphoric acid is a constituent part of the blood. Its presence was first ascertained by Manghini, who proved at the same time that it does not exist in the solid parts of animals. It is said to exist also in bile.

Manganese.

2. Manganese has been found in human hair, but scarcely in any other animal substance.

SECT. XII.

OF ANIMAL PRINCIPLES IN GENERAL.

Such are the properties of all the animal substances hitherto detected and accurately examined. They are by no means so numerous as the vegetable principles, owing in all probability to the chemical examination of animals having been hitherto confined to a small number, while a much more extensive range has been taken in the vegetable kingdom. The inferior animals, if we except a few insects, have attracted but little of the attention of chemists. I confess, too, that I have omitted on purpose an account of several principles which are well known to exist in the animal kingdom, merely

Substances omitted.

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because we know nothing so precise about their chemical properties as to enable us to class them properly. I may mention, as examples, the colouring matter of the cochineal insect, and that of the shell-fish with which the ancients dyed their purple. The reader will find a very full and interesting account of all that we know respecting these substances in Dr Bancroft's *Philosophy of Permanent Colours*. I may mention also the liquor emitted by the ink-fish, and the blistering principle in *cantharides*. Experiments, indeed, have been made on the last by Neumann, and others since his time; but they are still very incomplete, since we do not even know what the blistering principle is, tho' it is likely enough that it is a resin.

Almost the whole of the soft parts of animal bodies consist of gelatine, albumen, fibrin, and oil; while the basis of the hard parts is either phosphate or carbonate of lime. The other animal principles occur only in small quantities, and particular parts of the animal. The oils seldom enter into the structure of the organs of animals: they serve rather to lubricate the different parts, and to fill up interstices. Gelatine is insoluble in cold water, albumen insoluble in hot, and fibrin insoluble both in cold and hot.

Simple substances found in animals.

The simple bodies of which all of them consist are the following:

1. Azote	8. Soda
2. Carbon	9. Potash
3. Hydrogen	10. Muriatic acid
4. Oxygen	11. Magnesia
5. Phosphorus	12. Silica
6. Lime	13. Iron
7. Sulphur	14. Manganese

Of these, magnesia and silica may in a great measure be considered as foreign bodies; for they are only found in exceedingly minute quantities. The principle elementary ingredients are the first six: animal substances may be considered as in a great measure composed of them. The first four constitute almost entirely the soft parts, and the other two form the basis of the hard parts. But we will be able to judge of this much better after we have taken a view of the various parts of animals as they exist ready formed in the body. This shall be the subject of the next Chapter.

CHAP. II.

PARTS OF ANIMALS.

Solids. THE different substances which compose the bodies of animals may be arranged under the following heads:

1. Bones and shells	7. Glands
2. Horns and nails	8. Brain and nerves
3. Muscles	9. Marrow
4. Skin	10. Hair and feathers
5. Membranes	11. Silk and similar bodies.
6. Tendons and ligaments	

Besides these substances, which constitute the solid parts of the bodies of animals, there are a number of fluids, the most important of which is the *blood*, which pervades every part of the system in all the larger animals: The rest are known by the name of *secretions*, because they are formed, or *secreted* as the anatomists term it, from the blood. The principal animal secretions are the following:

Fluids.

1. Milk	9. Humours of the eye
2. Eggs	10. Mucus of the nose, &c.
3. Saliva	11. Sinovia
4. Pancreatic juice	12. Semen
5. Bile	13. Liquor of the amnios
6. Cerumen	14. Poisonous secretions
7. Tears	15. Air.
8. Liquor of the pericardium	

Various substances are separated either from the od or the food, on purpose to be afterwards thrown of the body as useless or hurtful. These are called *retions*. The most important of them are, Chap. II.

1. Sweat
2. Urine
3. Fæces.

Besides the liquids which are secreted for the dif-nt purposes of healthy animals, there are others ch make their appearance only during disease, and ich may therefore be called *morbid secretions*. The st important of these are the following:

Morbid secretions.

1. Pus
2. The liquor of dropsy
3. The liquor of blisters.

To these we must add several solid bodies, which occasionally formed in different cavities in conse-nce of the diseased action of the parts. They may called *morbid concretions*. The most remarkable of m are the following:

Morbid concretions.

1. Salivary calculi
2. Concretions in the lungs, liver, brain, &c.
3. Intestinal calculi
4. Biliary calculi
5. Urinary calculi
6. Gouty calculi.

These different substances shall form the subjects of : following sections:

SECT. I.

OF BONES, SHELLS, AND CRUSTS.

Bones, what.

By *bones* are meant those hard, solid, well-known substances, to which the firmness, shape, and strength of animal bodies are owing; which, in the larger animals, form as it were the ground work upon which all the rest is built. In man, in quadrupeds, and many other animals, the bones are situated below the other parts, and scarcely any of them are exposed to view; but shell-fish and snails have a hard covering on the outside of their bodies, evidently intended for defence. As these coverings, though known by the name of *shells*, are undoubtedly of a bony matter, I shall include them in this Section. For the very same reason, it would be improper to exclude *egg-shells*, and those coverings of certain animals, the lobster for instance, known by the name of *crusts*. The solid substances belonging to that class of bodies usually distinguished by the name of *zoophites*, may be included likewise without impropriety in this Section. As these different substances, though they belong to the same genus, are notwithstanding distinguished by peculiar properties, I shall consider each set separately.

I. Bones.

Properties.

The bones are the most solid part of animals. Their texture is sometimes dense, at other times cellular and

porous, according to the situation of the bone. They are white, of a lamellar structure, and not flexible nor softened by heat. Their specific gravity differs in different parts. That of adults teeth is 2·2727; the specific gravity of childrens teeth is 2·0833*. It must have been always known that bones are combustible, and that when sufficiently burnt, they leave behind them a white porous substance, which is tasetless, absorbs water, and has the form of the original bone. The nature of this substance embarrassed the earlier chemists. Beccher observed, that in a very violent heat it underwent a kind of fusion, and assumed an appearance analogous to that of porcelain. It was afterwards considered as a peculiar earth, and distinguished by the name of *animal earth* or *earth of bones*. Some chemists considered it as the same with lime; but the difference between it and that earth was too well marked to allow that opinion to gain ground. It had been long known that bones yielded a gelatinous substance when boiled in water; they had even been employed in the manufacture of glue. Hence it was obvious that they contained gelatine. It had been observed, that all acids had the property of softening them by dissolving their earthy and gelatinous constituents; and that when thus softened they resembled cartilage. These facts must have been known at a very early period, and afforded chemists some data for estimating their constituents.

Chap. II.

History.

In 1771, Scheele mentioned, in his dissertation on fluor spar, that the earthy part of bones is *phosphate of*

* Pepys, Fox on the *Teeth*, p. 99.

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*lime**. This discovery was the first and the great step towards a chemical knowledge of the composition of bones. Afterwards some new facts were made known by Berniard, Bouillon, and Rouelle: but for by far the most complete analyses which have hitherto appeared we are indebted to Mr Hatchett †, and to Fourcroy and Vauquelin ‡.

Constituents.

The component parts of bones are chiefly four; namely, the earthy salts, fat, gelatine, and cartilage.

1. Earthy salts.

1. The earthy salts may be obtained either by calcining the bone to whiteness, or by steeping it for a sufficient length of time in acids. In the first case, the salts remain in the state of a brittle white substance; in the second, they are dissolved, and may be thrown down by the proper precipitants. These earthy salts are four in number: 1. Phosphate of lime, which constitutes by far the greatest part of the whole. 2. Carbonate of lime. 3. Phosphate of magnesia, lately discovered by Fourcroy and Vauquelin. It occurs in the bones of all the inferior animals examined by these indefatigable chemists, but could not be detected in human bones. 4. Sulphate of lime, detected by Mr Hatchett in a very minute proportion.

To estimate these substances, calcined bones may be dissolved in nitric or muriatic acid. During the solution carbonic acid gas makes its escape §. Pure ammonia dropt into the solution throws down the phos-

* The discoverer of this has not been completely ascertained. Scheele does not claim it in that paper; Bergman gives it to Gahn; but Crell affirms that it was made by Scheele.

† *Phil. Trans.* 1799.

‡ *Ann. de Chim.* xlvii. 244.

§ Hatchett, *Phil. Trans.* 1799, p. 327.

phate of lime and phosphate of magnesia in the state of a fine powder, readily soluble without effervescence in nitric and muriatic acids. Nitrate of barytes afterwards causes a small precipitate insoluble in muriatic acid, and therefore consisting of sulphate of barytes. Its weight indicates the quantity of sulphuric acid in bones, from which the sulphate of lime which they contain may be estimated *. Carbonate of ammonia now throws down pure carbonate of lime †. These three constituents were found by Hatchett in all the bones of quadrupeds and fish which he examined. The carbonate scarcely exceeds the fifth part of the phosphate, and the proportion of sulphate is still smaller. As the proportion of phosphate of lime varies not only in different animals, but even in different bones of the same animal, and even in the same bone of different ages, no precise numbers can be given. To detect and estimate the phosphate of magnesia, Fourcroy and Vauquelin employed the following simple method: The bones, previously calcined and reduced to powder, were treated with their own weight of sulphuric acid, and the mixture left to macerate for five or six days. It was then diluted with water, edulcorated, and filtered. The filtered liquid was mixed with an excess of ammonia, which threw down a mixture of phosphate of lime and

* Hatchett, *Phil. Trans.* 1799, p. 327. The process described in the text was that employed by Mr Hatchett. As the bones which he examined were doubtless those belonging to the inferior animals, a little phosphate of magnesia-and-ammonia would probably remain after the liquid had been precipitated by ammonia. It is possible that the precipitate obtained with nitrate of barytes may be owing to the presence of this salt, and not to sulphate of lime.

† Hatchett, *Phil. Trans.* 1799, p. 327.

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ammonio-phosphate of magnesia. This precipitate is boiled in potash, which decomposes the magnesian salt, and leaves a mixture of magnesia and phosphate of lime. This mixture is treated with boiling acetous acid, which dissolves the magnesia, and leaves the phosphate of lime. The acetate of magnesia is decomposed by carbonate of soda, and the carbonate of magnesia obtained is dissolved in sulphuric acid *.

2. Fat.

2. The proportion of fat contained in bones is various. By breaking bones in small pieces, and boiling them for some time in water, Mr Proust obtained their fat swimming on the surface of the liquid. It weighed, he says, one-fourth of the weight of the bones employed †. This proportion appears excessive, and can scarcely be accounted for without supposing that the fat still retained water.

3. Gelatine.

3. The gelatine is separated by the same means as the fat, by breaking the bones in pieces and boiling them long enough in water. The water dissolves the gelatine, and gelatinizes when sufficiently concentrated. Hence the importance of bones in making portable soups, the basis of which is concrete gelatine, and likewise in making glue. By this process Proust obtained from powdered bones about $\frac{1}{16}$th of their weight of gelatine. This celebrated chemist has been at considerable pains to point out the advantage of employing powdered bones in the preparation of soups and broths; and Cadet de Vaux has lately published a set of experiments to show, that from bones thus powdered as much good soup may be obtained as from five times

* *Ann. de Chim.* xlvii. 247.

† *Jour. de Phys.* lii. 257

Chap. II.

heir weight of meat *. But when Dr Young repeated his improbable experiment it did not succeed †.

4. Cartilage.

4. When bones are deprived of their gelatine by boiling them in water, and of their earthy salts by steeping them in diluted acids, there remains a soft white lastic substance, possessing the figure of the bones, and nown by the name of *cartilage*. From the experinents of Hatchett, it appears that this substance has the roperties of coagulated albumen. Like that substance, t becomes brittle and semitransparent when dried, is eadily soluble in hot nitric acid, is converted into geatine by the action of diluted nitric acid; for it is solule in hot water, and gelatinises on cooling, and ammoia dissolves it and assumes a deep orange colour. Like oagulated albumen, it forms an animal soap with fixed lkalies ‡.

This cartilaginous substance is the portion of the one first formed. Hence the softness of these parts at rst. The phosphate of lime is afterwards gradually eposited, and gives the bone the requisite firmness. The gelatine and fat, especially the first, gave the bone he requisite degree of toughness and strength; for vhen they are removed the bone becomes brittle. The elative proportion of phosphate of lime and cartilage liffers exceedingly in different bones and in different nimals.

The following Table, drawn up by Merat-Guillot §, xhibits a comparative view of the relative proportion

* *Jour. de Chim.* iv. 95. *Jour. of the Royal Institut.* ii. 18.
† Ibid. p. 25. ‡ *Phil. Trans.* 1800.
§ *Ann. de Chim.* xxxiv. 71.

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of these ingredients in a variety of bones. The sulphate of lime which occurs only in a very small quantity, and also the phosphate of magnesia, have been confounded with phosphate of lime. By gelatine, I suppose, we must understand cartilage. The real gelatine is included more probably in the loss.

Table of the constituents of bones.

One hundred parts contain	Gelatine	Phosph. of lime.	Carb. of lime.	Loss.
Human bones from a burying ground	16	67	1·5	15·5
Do. dry, but not from under the earth	23	63	2	12
Bone of ox	3	93	2	2
——— calf	25	54	trace	21
——— horse	9	67·5	1·25	22·25
——— sheep	16	70	0·5	13·5
——— elk	1·5	90	1	7·5
——— hog	17	52	1	30
——— hare	9	85	1	5
——— pullet	6	72	1·5	20·5
——— pike	12	64	1	23
——— carp	6	45	0·5	48·5
Horse teeth	12	85·5	0·25	2·25
Ivory	24	64	0·1	11·15
Hartshorn	27	57·5	1	14·5

Ox bones, according to the analysis of Fourcroy and Vauquelin, are composed of

51·0 solid gelatine
37·7 phosphate of lime
10·0 carbonate of lime
1·3 phosphate of magnesia

100·0 *

* *Ann. de Chim.* xlvii. 258.

Chap. II.

From the calcined bones of horses and sheep, fowls, and fishes, they extracted about $\frac{1}{16}$th part of phosphate of magnesia.

Enamel.

The only bone hitherto observed altogether destitute of cartilage is the enamel of the teeth. When the raspings of bones are steeped in diluted acids, the cartilage alone remains undissolved. Now, when the raspings of enamel are treated in this manner, Mr Hatchett observed that the whole was dissolved without any residuum whatever *. If we believe Fourcroy and Vauquelin, the enamel of the teeth is composed of

72·9	phosphate of lime
27·1	gelatine and water
100·0 †	

But the most complete analysis of teeth has been made by Mr Pepys, and his results agree exactly with those of Hatchett. He found the enamel of the teeth composed of..................

78	phosphate of lime
6	carbonate of lime
16	loss and water
100 ‡	

It is exceedingly probable that part of this loss may have been owing to a portion of gelatine; for though enamel is destitute of cartilage, it is probably provided with gelatine. The nitric acid employed is known to be a good solvent of gelatine even when much diluted. The infusion of tan would have ascertained its presence.

* *Phil. Trans.* 1799, p 328.

† *Mem. de l'Instit.* ii. 284.

‡ Fox on the *Teeth*, p. 96.

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From the analysis of Mr Pepys, we learn that the teeth are composed as follows * :

Analysis of teeth.

	Roots of the Teeth.	Teeth of Adults.	First Teeth of Children.
Phosphate of lime	58	64	62
Carbonate of lime	4	6	6
Cartilage	28	20	20
Loss	10	10	12
Total	100	100	100

From this analysis, we see that teeth contain more phosphate and less cartilage than bone, and enamel more phosphate than teeth.

Fossil bones.

Mr Hatchett examined likewise *fossil* bones from the rock of Gibraltar. He found them to consist of phosphate of lime without any cartilage or soft animal part. Their interstices were filled with carbonate of lime. Hence they resemble exactly bones that have been burnt. They must, then, have been acted on by some foreign agent; for putrefaction, or lying in the earth, does not soon destroy the cartilaginous part of bones. On putting a human os humeri, brought from Hythe in Kent, and said to have been taken from a Saxon tomb, into muriatic acid, he found the cartilaginous residuum nearly as complete as in a recent bone. From the recent experiments of Morichini †, Klaproth ‡, and Fourcroy and Vauquelin §, we learn that fossil ivory and teeth of animals frequently contain a portion of fluate

* Fox on the *Teeth*, p. 96.
† *Phil. Mag.* xxiii. 265.
‡ Gehlen's *Jour.* iii. 625.
§ *Phil. Mag.* xxv. 26[illegible].

of lime. Morichini and Gay Lussac endeavoured to prove that this salt existed even in recent ivory, and that the enamel of the teeth was almost entirely composed of it*. But the experiments of Wollaston, Brande†, Fourcroy, and Vauquelin ‡, have shown that there does not exist any sensible portion of fluoric acid in these substances while recent. Berzelius, however, has recently announced that he separated 3 *per cent.* of fluate of lime from fresh teeth, and that he has detected it also in bones, nearly in the same proportion. He even affirms that it exists in urine §. And as his experiments appear to have been made with considerable care, it is probable that the results which he obtained are correct ||.

There is reason to conclude, from the recent experiments of Bouillon La Grange, that the blue-coloured mineral called *torquoise* is a species of fossil bone, and that it owes its colour to the presence of some phosphate of iron ¶.

II. Shells.

Under the name of *shells* I include all the bony coverings of the different species of shell fish. Egg shells, also, from the similarity of their texture, belong to the same head. For almost all the knowledge of these substances that we possess, we are indebted to the late

* *Phil. Mag.* xxiii. 265.
† Nicholson's *Jour.* xiii. 216.
‡ *Phil. Mag.* xxv. 266.
§ Gehlen's *Jour.* vi. 591.
|| His experiments will be found in Gehlen's *Jour.* Second Series, iii. 2. There is an abstract of them in *Ann. de Chim.* lxi. 256.
¶ *Phil. Mag.* xxvi. 220.

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important dissertations of Mr Hatchett. A few detached facts, indeed, had been observed by other chemists; but his experiments gave us a systematic view of the constituents of the whole class.

Shells, like bones, consist of calcareous salts united to a soft animal matter; but in them the lime is united chiefly to carbonic acid, whereas in bones it is united to phosphoric acid. In shells the predominating ingredient is carbonate of lime; whereas in bones it is phosphate of lime. This constitutes the characteristic difference in their composition.

Divided into two classes.

Mr Hatchett has divided shells into two classes. The first are usually of a compact texture, resemble porcelain, and have an enamelled surface, often finely variegated. The shells belonging to this class have been distinguished by the name of *porcelaneous shells*. To this class belong the various species of *voluta*, *cypræa*, &c. The shells belonging to the second class are usually covered with a strong epidermis, below which lies the shell in layers, and composed entirely of the substance well known by the name of *mother-of-pearl* *. They have been distinguished by the name of *mother-of-pearl shells*. The *shell* of the *fresh water muscle*, the *haliotis iris*, the *turbo olearius*, are examples of such shells. The shells of the first of these classes contain a very small portion of soft animal matter; those of the second contain a very large proportion. Hence we see that they are extremely different in their composition.

* Hérissant, *Mem. Par.* 1766, p. 22.—Hatchett, *Phil. Trans.* 1799, p. 327.

1. Porcelaneous shells, when exposed to a red heat, crackle and lose the colour of their enamelled surface. They emit no smoke or smell; their figure continues unaltered, their colour becomes opaque white, tinged partially with pale grey. They dissolve when fresh with effervescence in acids, and without leaving any residue; but if they have been burnt their remains always a little charcoal. The solution is transparent, gives no precipitate with ammonia or acetate of lead; of course it contains no sensible portion of phosphate or sulphate of lime. Carbonate of ammonia throws down an abundant precipitate of carbonate of lime. Porcelaneous shells, then, consist of carbonate of lime cemented together by a small portion of an animal matter, which is soluble in acids, and therefore resembles gelatine *.

1. Porcelaneous.

Composed of carbonate of lime and a little jelly.

Patellæ from Madeira, examined by Mr Hatchett, were found, like the porcelaneous shells, to consist of carbonate of lime; but when exposed to a red heat they emitted a smell like horn; and when dissolved in acids a semiliquid gelatinous matter was left behind. They contain therefore less carbonate of lime and more gelatine, which is of a more viscid nature than that of porcelaneous shells.

Patellæ.

2. Mother-of-pearl shells when exposed to a red heat crackle, blacken, and emit a strong fetid odour. They exfoliate, and become partly dark grey, partly a fine white. When immersed in acids they effervesce at first strongly; but gradually more and more feebly, till at last the emission of air-bubbles is scarcely perceptible.

2. Mother-of-pearl,

* Hatchett, *Phil. Trans.* 1799, p. 317.

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The acids take up only lime, and leave a number of thin membranous substances, which still retain the form of the shell. From Mr Hatchett's experiments, we learn that these membranes have the properties of coagulated albumen. Mother-of-pearl shells, then, are composed of alternate layers of coagulated albumen and carbonate of lime, beginning with the epidermis, and ending with the last formed membrane. The animals which inhabit these shells increase their habitation by the addition of a stratum of carbonate of lime, secured by a new membrane; and as every additional stratum exceeds in extent that which was previously formed, the shell becomes stronger as it becomes larger *.

Of membrane and carbonate of lime.

Though this in general is the structure of the mother-of-pearl shells, yet there is a considerable difference between the proportion of the component parts and the consistency of the albuminous part. Some of them, as the common oyster shell, approach nearly to the patellæ, the albuminous portion being small, and its consistence nearly gelatinous; while in others, as the *haliotis iris*, the *turbo olearius*, the real mother-of-pearl, and a species of fresh water muscle analysed by Hatchett, the membranes are distinct, thin, compact, and semitransparent †. Mother-of-pearl contains

66	carbonate of lime
24	membrane
100 ‡	

Pearl.

Pearl, a well known globular concretion which is formed in some of these shells, resembles them exactly

* Hatchett, *Phil. Trans*, 1799, p. 317. † Ibid.
‡ Merat-Guillot, *Ann. de Chim*. xxxiv. 71.

in its structure and composition. It is a beautiful substance of a bluish white colour, iridescent, and brilliant. It is composed of concentric and alternate coats of thin membrane and carbonate of lime. Their iridescence is obviously the consequence of the lamellated structure*.

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Bone of the cuttle fish.

Mr Hatchett found that what is called the *bone* of the *cuttle fish* is exactly similar to mother-of-pearl shells in its composition.

From the comparative analysis of shells and bones, Mr Hatchett was induced to compare them together, and has shown that porcelaneous shells bear a striking resemblance to enamel of teeth; while mother-of-pearl shells bear the same resemblance to the substance of teeth or bone: with this difference, that in enamel and bone the earthy salt is phosphate of lime, whereas in shells it is pure carbonate of lime.

III. Crusts.

By crusts we understand those bony coverings of which the whole external surface of crabs, lobsters, and other similar sea animals are composed. Mr Hatchett found them composed of three ingredients: 1. A cartilaginous substance, possessing the properties of coagulated albumen; 2. Carbonate of lime; 3. Phosphate of lime. By the presence of this last substance they are essentially distinguished from shells, and by the great excess of carbonate of lime above the phosphate they are equally distinguished from bones. Thus the

Constituents.

* Hatchett, *Phil. Trans.* 1799.

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Between shells and bones.

crusts lie intermediate between bones and shells, partaking of the properties and constitution of each. The shells of the eggs of fowls must be referred likewise to the class of crusts, since they contain both phosphate and carbonate of lime. The animal cement in them, however, is much smaller in quantity. From the experiments of Berniard and Hatchett, it is extremely probable that the shells of snails are composed likewise of the same ingredients, phosphate of lime having been detected in them by these chemists.

Mr Hatchett examined the crusts of crabs, lobsters, prawns, and cray fish. When immersed in diluted nitric acid these crusts effervesced a little, and gradually assumed the form of a yellowish-white soft elastic cartilage, retaining the form of the crust. The solution yielded a precipitate to acetate of lead, and ammonia threw down phosphate of lime. Carbonate of ammonia threw down a much more copious precipitate of carbonate of lime. On examining the crust which covers different species of *echini*, Mr Hatchett found it to correspond with the other crusts in its composition. Some species of star-fish yielded phosphate of lime, others none: hence the covering of that genus of animals seems to be intermediate between shell and crust.

Analysis.

With these observations of Mr Hatchett the analysis of Merat-Guillot corresponds. From lobster crust he obtained ....60 carbonate of lime
14 phosphate of lime
26 cartilage

100*

* *Ann. de Chim.* xxxiv. 71.

One hnndred parts of cray fish crust contain Chap. II.

60 carbonate of lime
12 phosphate of lime
28 cartilage

100*

One hundred parts of hens egg-shells contain Egg-shells.

89·6 carbonate of lime
5·7 phosphate of lime
4·7 animal matter

100·0†

IV. Zoophites.

Many of the substances called *zoophites* have the hardness and appearance of shell or bone, and may therefore be included among them without impropriety. Others, indeed, are soft, and belong rather to the class of membrane or horn; but of these very few only have been examined. Indeed scarcely any chemical experiments have been published on these interesting subjects, if we except the admirable dissertation by Hatchett in the Philosophical Transactions for 1800, which has been so often quoted. From this dissertation, and from a few experiments of Merat-Guillot, we learn that the hard zoophites are composed chiefly of three ingredients: 1. An animal substance of the nature of coagulated albumen, varying in consistency; sometimes Composition.

* Merat-Guillot, *Ann. de Chim.* xxxiv. 71.
† Vauquelin, Ibid. xxix. 6.

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being gelatinous and almost liquid, at others of the consistency of cartilage. 2. Carbonate of lime. 3. Phosphate of lime.

Divided into four classes.

In some zoophites the animal matter is very scanty, and phosphate of lime wanting altogether; in others the animal matter is abundant, and the earthy salt pure carbonate of lime; while in others the animal matter is abundant, and the hardening salt a mixture of carbonate of lime and phosphate of lime; and there is a fourth class almost destitute of earthy salts altogether. Thus there are four classes of zoophites; the first resemble porcelaneous shells, the second resemble mother-of-pearl shells, the third resemble crusts, and the fourth horn.

1. Composed of carbonate of lime and jelly.

1. When the *madrepora virginea* is immersed in diluted nitric acid it effervesces strongly, and is soon dissolved. A few gelatinous particles float in the solution, which is otherwise transparent and colourless. Ammonia precipitates nothing; but its carbonate throws down abundance of carbonate of lime. It is composed, then, of carbonate of lime and a little animal matter. The following zoophites yield nearly the same results:

Madrepora muricata
.... labyrinthica
Millepora cerulea
.... alcicornis
Tubipora musica.

2. Of carbonate of lime and membrane.

2. When the *madrepora ramea* is plunged into weak nitric acid, an effervescence is equally produced; but after all the soluble part is taken up, there remains a membrane which retains completely the original shape of the madrepore. The substance taken up is pure

lime. Hence this madrepore is composed of carbonate of lime, and a membranaceous substance which, as in mother-of-pearl shells, retains the figure of the madrepore. The following zoophites yield nearly the same results:

Madrepora fascicularis
Millepora cellulosa
.... fascialis
.... truncata
Iris hippuris

The following substances, analysed by Merat-Guillot, belong to this class from their composition, though it is difficult to say what are the species of zoophites which were analysed. By *red coral* he probably meant the *gorgonia nobilis*, though that substance is known, from Hatchett's analysis, to contain also some phosphate.

	White coral.	Red coral.	Articulated coraline.
Carbonate of lime..	50	53·5	49
Animal matter....	50	46·5	51
	100	100·0	100 *

3. Of membrane, carbonate, and phosphate.

3. When the *madrepora polymorpha* is steeped in weak nitric acid, its shape continues unchanged; there remaining a tough membranaceous substance of a white colour and opaque, filled with a transparent jelly. The acid solution yields a slight precipitate of phosphate of lime when treated with ammonia, and carbonate of ammonia throws down a copious precipitate of carbonate

* Merat-Guillot, *Ann. de Chim.* xxxiv. 71.

Book V. of lime. It is composed therefore of animal substance, partly in the state of jelly, partly in that of membrane, and hardened by carbonate of lime together with a little phosphate of lime.

Flustra foliacea, treated in the same manner, left a finely reticulated membrane, which possessed the properties of coagulated albumen. The solution contained a little phosphate of lime, and yielded abundance of carbonate of lime when treated with the alkaline carbonates. The *coralina opuntia*, treated in the same manner, yielded the same constituents; with this difference, that no phosphate of lime could be detected in the fresh coraline, but the solution of burnt coraline yielded traces of it. The *iris ochracea* exhibits the same phenomena, and is formed of the same constituents. When dissolved in weak nitric acid, its colouring matter falls in the state of a fine red powder, neither soluble in nitric nor muriatic acid, nor changed by them: whereas the tinging matter of the *tubipora musica* is destroyed by these acids. The branches of this iris are divided by a series of knots. These knots are cartilaginous bodies connected together by a membranous coat. Within this coat there is a conical cavity filled with the earthy or coraline matter; so that, in the recent state, the branches of the iris are capable of considerable motion, the knots answering the purpose of joints.

When the *gorgonia nobilis*, or red coral, is immersed in weak nitric acid, its colouring matter is destroyed, an effervescence takes place, and the calcareous part is dissolved. There remains an external tubulated membrane of a yellow colour, inclosing a transparent gelatinous substance. The solution yields only carbonate

of lime: but when red coral is heated to redness, and then dissolved, the solution yields a little phosphate of lime also. Red coral is composed of two parts: an internal stem, composed of gelatinous matter and carbonate of lime; and an external covering or cortex, consisting of membrane hardened by the calcareous salts, and both coloured by some unknown substance.

The *gorgonia ceratophyta* likewise consists of a stem and cortex. The stem is composed of cartilage, hardened chiefly by phosphate of lime, and containing little carbonate of lime; but the cortex consists of membrane hardened almost entirely by carbonate of lime. The *gorgonia flabellum* is almost exactly similar. The cortex of the *gorgonia suberosa* yielded gelatine to boiling water; when steeped in acids, it left a soft yellowish membrane, and the acid had taken up a little phosphate and a large portion of carbonate of lime. The stem contained scarcely any earthy salt. When burnt, it left a little phosphate of lime. To water it yielded a little gelatine; but it consisted chiefly of a horny substance, analogous to coagulated albumen. The *gorgonia setosa* and *pectinata* exhibited the same phenomena.

4. Chiefly of membrane.

4. *Gorgonia antiphates*, like the other species of gorgonia, has a horny stem, but it is destitute of a cortex. To boiling water it gives out some gelatine. When steeped in nitric acid it becomes soft, and exhibits concentric coats of thin opaque brown membranes, of a ligneous aspect. It contains no earthy salt. With potash it forms an animal soap, and possesses nearly the properties of horn.

The stems of the *gorgonia umbraculum* and *verrucosa* resemble that of the gorgonia antiphates; but these are

Book V. both provided with a cortex composed of membrane and carbonate of lime.

The *antiphates ulex* and *myriophyla* resemble almost exactly the horny stem of the gorgonia antiphates.

Mr Hatchett analysed many species of sponges, but found them all similar in their composition. The *spongia cancellata, oculata, infundibuliformis, palmata,* and *officinalis,* may be mentioned as specimens. They consist of gelatine, which they gradually give out to water, and a thin brittle membranous substance, which possesses the properties of coagulated albumen. Hence the effect of acids and alkalies on them.

The *alcyonium ficus, asbestinum,* and *arboreum,* resemble very much the cortex of the gorgonia suberosa in their composition. They yield a little gelatine to water. In nitric acid they soften, and appear membranous. The acid takes up the carbonate of lime, and likewise a little phosphate, at least when the substance has been previously heated to redness.

Such is an abstract of Mr Hatchett's instructive analysis of the zoophites.

SECT. II.

OF HORNS, NAILS, AND SCALES.

In the last Section I treat[illegible] [illegible]ose hard parts of animals which were inflexi[illegible] [illegible]apable [illegible] softened by heat, and whic[illegible] [illegible] a gr[illegible] of calcareous salts; but ther[illegible]

parts which possess considerable elasticity, which are softened by heat, and which contain but a very small portion of calcareous matter. This set comprehends the substances well known under the names of *horn*, *nails*, and *scales*. The fourth class of zoophites ought, in strict propriety, to be joined to them; but in the present state of our knowledge I thought it better to give a view of all that is known of the zoophites in one place.

Almost all that we know of these bodies has been discovered by Mr Hatchett. Many experiments, indeed, had been made by preceding chemists; but not of such a nature as to throw much light upon their composition.

1. *Horns* are well known substances that are attached to the foreheads of oxen, sheep, and various other animals. They are not very hard, as they may be easily cut with a knife or rasped with a file; but they are so tough as not to be capable of being pounded in a mortar. When in thin plates they have a degree of transparency, and have been sometimes substituted for glass in windows. When heated sufficiently they become very soft and flexible, so that their shape may be altered considerably. Hence they may be gradually squeezed into a mould, and wrought into various forms, as is well known. When strongly heated in a Papin's digester, they are said to be converted into a gelatinous mass, which possesses the properties of gelatine. Horns.

The quantity of earthy matter which they contain is exceedingly small. Mr Hatchett burnt 500 grains of ox horn. The residuum was only 1·5 grain, and the half of this was phosphate of lime. Seventy-[illegible]ains of the horn of the chamois left only 0·5 Composed of membrane.

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of residue of which less than the half was phosphate of lime *. They consist chiefly of a membranous substance, which possesses the properties of coagulated albumen; and probably they contain also a little gelatine. Hence we see the reason of the products that are obtained when these substances are subjected to distillation.

The horns of the hart and buck must, however, be excepted. From the experiments of Scheele and Rouelle, together with those of Hatchett, we know that these substances possess exactly the properties of bone, and are composed of the same constituents, excepting only that the proportion of cartilage is greater. They are intermediate, then, between bone and horn. The same remarks apply to a fossil horn found in France and lately analysed by Braconnot. He found it composed of

Siliceous sand	4·0
Gelatine	4·6
Bitumen	4·4
Oxide of iron	0·5
Alumina	0·7
Phosphate of magnesia	1·0
Water	11·0
Carbonate of lime	4·5
Phosphate of lime	69·3
	100·0 †

Nails.

2. The *nails*, which cover the extremities of the fingers, are attached to the epidermis, and come off along with it. Mr Hatchett has ascertained that they are

* *Phil. Trans.* 1779, p. 332.

† Gehlen's *Jour.* 2d Series, iii. 45.

Chap. II.

composed chiefly of a membranous substance, which possesses the properties of coagulated albumen. They seem to contain also a little phosphate of lime. Water softens but does not dissolve them; but they are readily dissolved and decomposed by concentrated acids and alkalies. Hence it appears that nails agree with horn in their nature and composition. Under the head of nails must be comprehended the talons and claws of the inferior animals, and likewise their hoofs, which differ in no respect from horn.

Tortoise-shell.

The substance called tortoise-shell is very different from shells in its composition, and approaches much nearer to the nature of *nail;* for that reason I have placed it here. When long macerated in nitric acid, it softens, and appears to be composed of membranes laid over each other, and possessing the properties of coagulated albumen. When burnt, 500 grains of it yield three of earthy matter, consisting of phosphate of lime and soda, with a little iron *.

Scales.

3. The *scales* of animals are of two kinds; some, as those of serpents and other amphibious animals, have a striking resemblance to horn; while those of fish bear a greater resemblance to mother-of-pearl. The composition of these two kinds of shells is very different.

1. Of fish.

Composed of membrane and phosphate.

The scales of fish, as had been observed by Lewenhoeck, are composed of different membranous laminæ. When immersed for four or five hours in nitric acid, they become transparent, and perfectly membranaceous. The acid, when saturated with ammonia, gives a copious precipitate of phosphate of lime †. Hence they are

* Hatchett, *Phil. Trans.* 1799, p. 332.

† Id. Ibid.

parts. Of these, the muscles naturally claim our attention in the first place, as being the most important. Chap. II.

The muscular parts of animals are known in common language by the name of *flesh*. They constitute a considerable proportion of the food of man.

Muscular flesh is composed of a great number of fibres or threads, commonly of a reddish or whitish colour; but its appearance is too well known to require any description. Hitherto it has not been subjected to any accurate chemical analysis. Mr Thouvenel, indeed, has published a very valuable dissertation on the subject; and it is to him that we are indebted for almost all the facts known concerning the composition of muscle. Some curious experiments have also been made by Fourcroy and Vauquelin; and Mr Hatchett has not neglected this part of the subject in his interesting dissertations on animal substances.

History.

It is scarcely possible to separate the muscle from all the other bodies with which it is mixed. A quantity of fat often adheres to it closely; blood pervades the whole of it: and every fibre is enveloped in a particular thin membranous matter, which anatomists distinguish by the name of *cellular substance*. The analysis of the muscle, then, cannot be supposed to exhibit an accurate view of the composition of pure muscular fibres, but only of muscular fibre not perfectly separated from other substances.

Action of cold water.

1. When a muscle is cut in small pieces, and well washed with water, the blood and other liquids contained in it are separated, and part of the muscular substance also is dissolved. The muscle, by this process, is converted into a white fibrous substance, still retaining the form of the original body. The water assumes

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the colour which results from mixing water with some blood. When heated it coagulates; brown flakes swim on the surface, consisting of albumen combined with the colouring matter of the blood: some fibrin likewise precipitates. If the evaporation be continued, more albumen precipitates, and at last the whole assumes the form of a jelly. When evaporated to dryness, and treated with alcohol, the gelatine thus formed, together with a little phosphate of soda and of ammonia, remains undissolved; but the alcohol dissolves a peculiar *extractive* matter, first observed by Thouvenel. This matter may be obtained by evaporating the alcohol to dryness. It has a reddish brown colour, a strong acrid taste, and aromatic odour. It is soluble both in water and alcohol; and when its watery solution is very much concentrated, it assumes an acid and bitter taste. It swells upon hot coals, and melts, emitting an acid and penetrating smell. It attracts moisture from the air, and forms a saline efflorescence. In a hot atmosphere it becomes sour and putrefies. When distilled it yields an acid partly combined with ammonia.

Of hot water.

2. If the muscle, after being thus treated with cold water, be boiled for a sufficient time in water, an additional portion of the same substances are separated from it. Some albumen collects on the surface in the form of scum, accompanied with some melted fat. The water, when sufficiently concentrated by evaporation, assumes the form of a jelly. When evaporated to dryness, and treated with alcohol, the gelatine and phosphoric salts remain, while the extractive matter of Thouvenel is dissolved, and may be obtained by evaporating to dryness. It is by this process that it is procured in a sufficient quantity for examination, cold

water abstracting only a very small portion from the muscle. Chap. II.

Insoluble part.

3. The muscle, thus treated with water, is left in the state of grey fibres, insoluble in water, and becoming brittle when dry. This substance possesses all the properties of *fibrin*.

Constituents.

4. From these facts, ascertained by Thouvenel and Fourcroy *, it appears that the muscles are composed chiefly of fibrin, to which they owe their fibrous structure and their form, and that they contain also

2. Albumen	5. Phosphate of soda
3. Gelatine	6. Phosphate of ammonia
4. Extractive	7. Phosph. of lime and carb. of do.

For the discovery of the last ingredients we are indebted to Mr Hatchett, who found that 500 parts of beef muscle left, after combustion, a residuum of 25·6 parts, consisting chiefly of these salts. When muscles are long boiled in water, Mr Hatchett found that the greater part of the phosphate of lime, as well as of the alkaline phosphates, was dissolved; for the muscle, after this treatment, when dissolved in nitric acid, yielded scarcely any phosphate of lime; whereas if it was dissolved directly in nitric acid, a precipitate of phosphate of lime was thrown down by ammonia. Hence it would appear, either that the phosphate of lime is united to gelatine, or that it is rendered soluble by means of it. The carbonate of lime still remains after the action of water, and is converted into oxalate when the muscle is treated with nitric acid.

Fourcroy and Vauquelin have likewise detected the

* Fourcroy, ix. 242.

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ese. Very little ammonia was given out during the cess*.

Different kinds of muscles.

. The muscles of different animals differ exceeding- rom each other in their appearance and properties, east as articles of food; but we know little of their mical differences. The observations of Thouvenel ie were directed to that object, and they are imper- . The flesh of the *ox* contains, according to him, greatest quantity of insoluble matter, and leaves the atest residuum when dried; the flesh of the *calf* is e aqueous and mucous: the land and water *turtle* ds more matter to water than the muscle of the ox; Thouvenel ascribes the difference to foreign bodies, igaments, &c. mixed with the muscle of the turtle: *ls* yield to water a quantity of matter intermediate veen that given by beef and veal: with them the cles of *frogs*, *cray fish*, and *vipers*, agree nearly in respect; but the muscles of fresh water fish, not- hstanding their softness, yield a considerably small- roportion †.

. When meat is boiled, it is obvious that the gela- , the extractive, and a portion of the salts, will be rated, while the coagulated albumen and fibrin will ain in a solid state. Hence the flavour and the nou- ing nature of soups derived from the extractive and tine. When meat is roasted, on the other hand, all e substances continue in it, and the taste and odour he extractive is greatly heightened by the action of

* *Mem. d'Arcueil*, i. 333.

Some experiments on the gizzards or muscular stomachs of fowls been published by Bouillon La Grange. See Nicholson's *Journal*, 206.

Book V. the fire. Hence the superior flavour of roasted meat. Fourcroy supposes that the brown crust which forms on roasted meat is composed entirely of the extractive.

SECT. IV.

OF THE SKIN.

The skin is that strong thick covering which envelopes the whole external surface of animals. It is composed chiefly of two parts: a thin white elastic layer on the outside, which is called *epidermis* or *cuticle*; and a much thicker layer, composed of a great many fibres closely interwoven, and disposed in different directions; this is called the *cutis*, or *true skin*. The epidermis is that part of the skin which is raised in blisters.

Epidermis. 1. The epidermis is easily separated from the cutis by maceration in hot water. It possesses a very great degree of elasticity.

It is totally insoluble in water and in alcohol. Pure fixed alkalies dissolve it completely, as does lime likewise, though slowly *. Sulphuric and muriatic acids do not dissolve it, at least they have no sensible action on it for a considerable time; but nitric acid soon deprives it of its elasticity, and causes it to fall to pieces †. It is well known that the living epidermis is tinged yel-

* Chaptal, *Ann. de Chim.* xxii. 221. But Davy could obtain no solution.
† Cruikshanks on *Insensible Perspiration*, p. 32.

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w almost instantaneously by nitric acid; but this ef-
t does not take place, at least so speedily, when the
d cuticle is plunged in nitric acid altogether *.

If the cuticle be tinged with nitric acid, the applica-
n of ammonia to it is well known to give it instanta-
usly a deep orange colour. Now, as Hatchett has
wn that this change is also produced upon coagula-
albumen in the same circumstances, and as the epi-
mis resembles that substance in all the properties
ve detailed, it can scarcely be doubted that it is any
ng else than a peculiar modification of coagulated al-
nen.

Cutis.

2. The cutis is a thick dense membrane, composed
fibres interwoven like the texture of a hat. When it
macerated for some hours in water, and agitation and
ssure are employed to accelerate the effect, the blood,
l all the extraneous matter with which it was loaded,
separated from it, but its texture remains unaltered.
evaporating the water employed, a small quantity
gelatine may be obtained. No subsequent macera-
n in cold water has any farther effect. When distill-
it yields the same products as fibrin. The concen-
ted alkalies dissolve it, converting it into oil and am-
nia. Weak acids soften it, render it transparent,
l at last dissolve it. Nitric acid converts it into oxa-
acid and fat, while, at the same time, azotic gas and
ssic acid are emitted †. When heated it contracts,
l then swells, exhales a fetid odour, and leaves a dense
rcoal, difficult to incinerate. By spontaneous de-

* Cruikshanks on *Insensible Perspiration*, p. 32.
† Fourcroy, ix. 254.

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composition in water or moist earth, it is converted into a fatty matter and into ammonia, which compose a kind of soap *. When allowed to remain long in water, it softens and putrefies, being converted into a kind of jelly. When long boiled in water it becomes gelatinous, and dissolves completely, constituting a viscid liquor, which, by proper evaporation, is converted into glue. Hence the cutis of animals is commonly employed in the manufacture of glue.

A species of gelatine.

From these facts the cutis appears to be a peculiar modification of gelatine enabled to resist the action of water, partly by the compactness of its texture, and partly by the viscidity of the gelatine of which it is formed; for those skins which dissolve most readily in boiling water afford the worst glue. Mr Hatchett has observed that the viscidity of the gelatine obtained from skins is nearly inversely as their flexibility, the supplest hides always yielding the weakest glue; but this glue is very soon obtained from them by hot water. The skin of the eel is very flexible, and affords very readily a great proportion of gelatine. The skin of the shark also readily yields abundance of gelatine; and the same remark applies to the skins of the hare, rabbit, calf, and ox; the difficulty of obtaining the glue and its goodness always increasing with the toughness of the hide. The hide of the rhinoceros, which is exceedingly strong and tough, far surpasses the rest in the difficulty of solution and in the goodness of its glue. When skins are boiled, they gradually swell and assume the appearance of horn: then they dissolve slowly.

* Fourcroy, ix. 254.

Leather.

3. It is from the skin or cutis of animals that leather is formed; and the goodness of the leather, or at least its strength, depends in some measure on the toughness of the hides. Those easily soluble, as seal skins, afford a weaker leather than those which are more difficultly soluble in water. The process by which the skins of animals are converted into leather is called *tanning*. It seems to have been known and practised in the earliest ages; but its nature was totally unknown till after the discovery of the *tanning principle* by Seguin. That chemist ascertained that leather is a compound of *tannin* and *skin*; that it is to the tannin that leather owes its insolubility and its power of resisting putrefaction. The subject has lately engaged the attention of Mr Davy, who has examined it with his usual ingenuity, and added several important facts to our former knowledge.

Preparation of the skins.

When skins are to be tanned, the first step of the process is to deprive them of their hair and cuticle. This is either done by steeping them in water till they begin to putrefy, or by steeping them in lime and water. The lime seems to combine with the cuticle, and to render it brittle and easily detachable from the hide. It produces the same effect upon the hair and the matter at its root *. When the hides have been steeped for a sufficient time, they are taken out, the hair, cuticle, &c. scraped off, and then they are washed in water.

After this preliminary process, the skins are subjected to different treatment according to the kind of leather which is to be made.

The large and thick hides are introduced for a short

* Davy, *Journal of the Royal Instit.* ii. 30.

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time into a strong infusion of bark. They are then said to be *coloured*. After this they are put into water slightly impregnated with sulphuric acid, or with the acid evolved during the fermentation of barley and rye. This renders them harder and denser than they were before, and fits them for forming sole leather. Mr Davy thinks, that by this process a triple compound is formed of the *skin*, *tan*, and *acid* *.

The light skins of cows, those of calves, and all small skins, are steeped for some days in a liquid made by the infusion of pigeon's dung in water. This liquid is called the *grainer*. By this process they are made thinner and softer and more proper for making light leather. Mr Davy considers the effect of this liquid to depend upon the fermentation which it undergoes; for dung that has undergone fermentation does not answer the purpose †.

After these preliminary processes, the skins are exposed to the action of the infusion of bark till they are converted into leather.

Process of tanning.

The infusion of oak bark contains two ingredients, namely, *tannin* and an *extractive*. The first is more soluble than the second. Hence, in saturated infusions there is a much greater proportion of tannin than of extractive; whereas in weak infusions the extractive bears a greater proportion to the tannin. Mr Davy considers it as doubtful whether the infusion of oak bark contains any gallic acid. This chemist has ascertained, that the hides extract both the tannin and extractive from the

* Davy, *Journals of the Royal Instit.* ii. 31.

† Ibid. p. 32.

‡ Ibid. p. 32.

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on, and leave nothing behind but pure water, pro- they be employed in sufficient quantity. Hence bvious, that both the tannin and extractive must into the composition of leather. The extractive the hide a brown colour, but does not render it ble in boiling water; the tannin renders it inso- , but its colour continues whitish. Hence it is that the lightest kinds of leather contain little else annin, while the brown kinds contain both tannin xtractive. While the hides are allowed to remain e infusion of bark, they combine of course with n and extractive, and the new compound is leather. e the reason of the increase of its weight.

lf skins, and those hides which are prepared by *rainer*, are first steeped in weak infusions of oak , and gradually removed to stronger and stronger, ey are completely impregnated, which takes up two to four months. As the weak infusions con- a greater proportion of extractive, the consequence is process is, that the skin combines in the first with a portion of it, and afterwards with the tan- When saturated solutions of tannin are employed, leather is formed in a much shorter time. This the process recommended by Seguin; but it has observed, that leather tanned in this way is more and more liable to crack than leather tanned in the way. Hence it is likely, as Davy has observed, the union of the extractive is requisite to form pli- and tough leather. Leather rapidly tanned must ss equable in its texture than leather slowly tanned, e surface must be saturated with tannin before the d has time to penetrate deep. Mr Davy has as-

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certained that skins, while tanning, seldom absorb more than ⅓d of their weight of vegetable matter.

Skins intended for sole leather are generally kept from the first in an infusion preserved nearly saturated by means of the strata of bark with which they alternate. The full impregnation requires from ten to eighteen months. It is likely, from this process, that sole leather contains a greater proportion of tannin than soft leather. While drying, it is smoothed with a rolling pin, and beat with a mallet, which must add considerably to its density *.

Rete mucosum.

4. As to the *rete mucosum*, or the mucous substance, situated between the cutis vera and epidermis, its composition cannot be determined with precision, because its quantity is too small to admit of examination. It is known that the black colour of negroes depends upon a black pigment, situated in this substance. Oxymuriatic acid deprives it of its black colour, and renders it yellow. A negro, by keeping his foot for some time in water impregnated with that acid, deprived it of its colour, and rendered it nearly white; but in a few days the black colour returned again with its former intensity †. This experiment was first made by Dr Beddoes on the fingers of a negro ‡.

* See Davy on the *Preparation of Skin for Tanning*. *Royal Instit.* i. 3?.

† Fourcroy, ix. p. 259.

‡ Beddoes on *Factitious Airs*, p. 45.

Chap. II.

SECT. V.

OF MEMBRANES, TENDONS, LIGAMENTS, AND GLANDS.

[T]HESE substances have not hitherto been subjected to [a] rigid chemical analysis. But from the properties [w]hich have been observed, they appear to have a closer [re]semblance to the skin than to any other animal sub[st]ance.

Membranes

1. The membranes are thin semitransparent bodies [w]hich envelope certain parts of the body, especially the [vi]scera; such as, the dura and pia mater, the pleura, [th]e peritoneum, the periosteum, &c. These substances [ar]e soft and pliable; when macerated in water, they [s]well, and become somewhat pulpy; and by continued [de]coction in hot water they are almost completely dis[so]lved, and the solution concretes into gelatine. They [ar]e convertible of course into the same substance as the [cu]tis by decoction; hence we must consider their com[po]sition as similar. Like hides they may also be tan[ne]d and converted into leather. From the experiments [o]f Mr Hatchett, it appears that they contain no phos[p]hate of lime as a constituent part, and scarcely any sa[li]ne ingredients; for when calcined they leave but a [v]ery inconsiderable residuum. Thus 250 grains of [h]og's bladder left only 0·02 grain of residuum *.

Resemble skin.

* *Phil. Trans.* 1799, p. 333.

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Tendons.

2. The tendons are strong, pearl-coloured, brilliant bodies, which terminate the muscles, and attach them to the bones, and are known in common language by the name of *sinews*. When boiled they assume the form of a semitransparent gelatinous substance, of a pleasant taste, well known in boiled meat. If the decoction be continued they dissolve completely, and are converted into gelatine. From these facts we are authorized to conclude, that the composition of the tendons is similar to that of the membranes and cutis.

Ligaments.

3. The ligaments are strong bands which bind the bones together at the different joints : they are fibrous substances, very dense and strong, and somewhat elastic. When boiled they yield a portion of gelatine, but they resist the action of water with great obstinacy, and after a great deal of boiling retain their form, and even their strength. The ligaments, then, differ essentially from the two last species. How far they resemble coagulated albumen remains to be ascertained. It is not unlikely that they will form a genus apart.

Glands.

4. The glands are a set of bodies employed to form or to alter the different liquids which are employed for different purposes in the animal body. There are two sets of them : the *conglobate*, which are small, scattered in the course of the lymphatics; and the *conglomerate*, such as the liver, kidneys, &c. Fourcroy supposes the first of these to be composed of gelatine ; but this is not very probable. The structure of the large glands has been examined by anatomists with great care ; but we are still ignorant of their composition. Indeed the present state of chemistry scarcely admits of an accurate analysis of these complicated bodies.

SECT. VI.

OF THE BRAIN AND NERVES.

The brain and nerves are the instruments of sensation, and even of motion; for an animal loses the power of moving a part the instant that the nerves which enter it are cut.

The brain and nerves have a strong resemblance to each other; and it is probable that they agree also in their composition. But hitherto no attempt has been made to analyse the nerves. The only chemists who have examined the nature of *brain* are Mr Thouret * and Mr Fourcroy †.

Properties of brain.

The brain consists of two substances, which differ from each other somewhat in colour, but which, in other respects, seem to be of the same nature. The outermost matter, having some small resemblance in colour to wood-ashes, has been called the *cineritious* part; the innermost has been called the *medullary* part.

Brain has a soft feel, not unlike that of soap; its texture appears to be very close; its specific gravity is greater than that of water.

When brain is kept in close vessels so that the external air is excluded, it remains for a long time unaltered. Fourcroy filled a glass vessel almost completely with pieces of brain, and attached it to a pneumatic appa-

* *Jour. de Phys.* xxxviii. 329. † *Ann. de Chim.* xvi. 282.

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ratus; a few bubbles of carbonic acid gas appeared at first, but it remained above a year without undergoing any farther change *.

This is very far from being the case with brain exposed to the atmosphere. In a few days (at the temperature of 60°) it exhales a most detestable odour, becomes acid, assumes a green colour, and very soon a great quantity of ammonia makes its appearance in it.

Action of cold water,

Cold water does not dissolve any part of the brain; but by trituration in a mortar it forms, with water, a whitish-coloured emulsion, which appears homogeneous, may be passed through a filter, and the brain does not precipitate by rest. When this emulsion is heated to 145°, a white coagulum is formed. The addition of a great quantity of water also causes a coagulum to appear, which swims on the surface, but the water still retains a milky colour. When sulphuric acid is dropt into the watery emulsion of brain, white flakes separate and swim on the surface, and the liquid becomes red. Nitric acid produces the same effects, only the liquid becomes yellow. Alcohol also separates a white coagulum from the emulsion, after it has been mixed with it for some hours. When nitric acid is added to the emulsion till it becomes slightly acid, a coagulum is also separated. This coagulum is of a white colour; it is insoluble in water and in alcohol. Heat softens, but does not melt it. When dried it becomes transparent, and breaks with a glassy fracture. It has therefore some resemblance to *albumen* †.

Of sulphuric acid.

When brain is triturated in a mortar with diluted

* *Ann. de Chim.* xvi. 297. † Ibid. p. 288.

sulphuric acid, part is dissolved; the rest may be separated, by filtration, in the form of a coagulum. The acid liquor is colourless. By evaporation, the liquid becomes black, sulphurous acid is exhaled, and crystals appear; and when evaporated to dryness, a black mass remains behind. When this mass is diluted with water, a quantity of charcoal separates, and the water remains clear: The brain is completely decomposed, a quantity of ammonia combines with the acid and forms sulphate of ammonia, while charcoal is precipitated. The water, by evaporation and treatment with alcohol, yields sulphates of ammonia and lime, phosphoric acid, and phosphates of soda and ammonia. Brain therefore contains

Chap. II.

Phosphate of lime
.... soda
.... ammonia.

Traces also of sulphate of lime can be discovered in it. The quantity of these salts is very small; altogether they do not amount to $\frac{1}{133}$th part *.

Of nitric acid,

Diluted nitric acid, when triturated with brain, likewise dissolves a part, and coagulates the rest. The solution is transparent. When evaporated till the acid becomes concentrated, carbonic acid gas and nitrous gas are disengaged; an effervescence takes place, white fumes appear, an immense quantity of ammonia is disengaged, a bulky charcoal remains mixed with a considerable quantity of oxalic acid †.

When brain is gradually evaporated to dryness by the heat of a water bath, a portion of transparent liquid

* Ann. de Chim. xvi. 288. † Ibid. 307.

separates at first from the rest, and the residuum, when nearly dry, acquires a brown colour; its weight amounts to about one-fourth of the fresh brain. It may still be formed into an emulsion with water, but very soon separates again spontaneously.

Of alcohol, When alcohol is repeatedly boiled upon this dried residuum till it ceases to have any more action, it dissolves about five-eighths of the whole. When this alcohol cools, it deposites a yellowish white substance, composed of brilliant plates. When kneaded together by the fingers, it assumes the appearance of a ductile paste: at the temperature of boiling water it becomes soft, and when the heat is increased it blackens, exhales empyreumatic and ammoniacal fumes, and leaves behind it a charry matter *. When the alcohol is evaporated, it deposites a yellowish black matter, which reddens paper tinged with turnsole, and readily diffuses itself through water †.

Of potash. Pure concentrated potash dissolves brain, disengaging a great quantity of ammonia.

These facts are sufficient to show us that, exclusive of the small proportion of saline ingredients, brain is composed of a peculiar matter, differing in many particulars from all other animal substances, but having a considerable resemblance in many of its properties to albumen. Brain has been compared to a soap; but it is plain that the resemblance is very faint, as scarcely any oily matter could be extracted from brain by Fourcroy, though he attempted it by all the contrivances which the present state of chemistry suggested; and the

* *Ann. de Chim.* xvi. 313.

† Ibid. 317.

alkaline portion of it is a great deal too small to merit any attention. Chap. II.

SECT. VII.

MARROW.

The hollows of the long bones are in living animals filled with a peculiar species of fat matter, to which the name of *marrow* has been given. In some bones this matter is a good deal mixed with blood, and has a red colour; in others, as the thigh bones, it is purer, and has a yellow colour. Various experiments on this matter were made by the older chemists, showing it to be analogous to animal fats *, and pointing out some of its peculiarities. Berzelius has lately examined it in detail, and published the results of his experiments †. The marrow on which his trials were made was obtained from the thigh bone of an ox.

Action of cold water.

1. When marrow is digested in cold water it becomes lighter coloured, while the water acquires the colour which it would have received had it been digested on blood. When this water is boiled it becomes muddy, and a dark brown matter precipitates. This matter consists of coagulated albumen mixed with some phos-

* Neumann's *Chemistry*, p. 560.

† Gehlen's *Jour.* Second Series, ii. 287.

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phate of lime, and phosphate of iron. A small portion of a yellow coloured salt is dissolved by the action of alcohol or water. This matter separated from marrow by water, is obviously owing to the blood with which it was mixed. The quantity which Berzelius obtained from marrow amounted to $\frac{1}{100}$th part of the whole. The portion of it dissolved by water and alcohol consisted partly of gelatine and common salt, and partly of the peculiar extractive matter obtained by Thouvenel from the muscles of animals, and described in the Third Section of this Chapter. The proportion of these substances obtained by Berzelius from marrow, amounted to about $\frac{1}{100}$th part of the whole.

Of hot water.

2. When marrow is boiled in water, the greatest part of it melts and swims upon the surface of the liquid. The water is at first muddy and milky, but becomes transparent on standing. When passed through the filter a substance is separated, which becomes greyish green, and semitransparent when dry. More of this matter precipitates when the liquid is evaporated. When the water is evaporated to dryness, a substance is obtained of a sharp aromatic taste like the marrow of roasted meat. These two substances consist chiefly of extractive, gelatine, and a peculiar substance which approaches the nature of albumen in its properties.

3. When marrow, thus purified, is melted in water and passed through a cloth, a quantity of blood vessels and skins remain upon the cloth, amounting to about $\frac{1}{100}$th part of the whole.

Properties of pure marrow.

4. Marrow, thus freed from its impurities, has a white colour with a shade of blue; its taste is insipid and rather sweetish. It softens by the heat of the hand,

Chap. II.

and melts when heated to 113° *. When cooled slowly it crystallizes in sphericles like olive oil. It burns with a flame like tallow. When distilled it gives first a transparent fluid yellowish oil, accompanied by carbonic acid gas, water, and heavy inflammable air. Afterwards there comes over a white solid oil, accompanied by a less copious evolution of gaseous bodies, and which does not become dark coloured, as happens when tallow is distilled. This had already been observed by Neumann. This solid oil has a disagreeable smell, amounts to 0·8 of the marrow distilled, reddens vegetable blues, and when boiled in water gives out a portion of sebacic acid, which Berzelius considers as benzoic acid.

The empyreumatic oil combines readily with alkalies and their carbonates. With the latter it forms a snow white soap, insoluble in water, though it increases in bulk when placed in contact with that liquid. It combines also with the earths, and forms soaps likewise insoluble in water.

The water which comes over during the distillation of marrow is colourless, has a fetid and sour smell, and an empyreumatic taste. It contains a little acetic acid, empyreumatic oil, and probably benzoic acid; but exhibits no traces of ammonia.

The gaseous products amount to $\frac{1}{10}$th of the marrow distilled. They contain no sulphur nor phosphorus, and consist of carbonic acid and heavy inflammable air, which burns with a white flame, and seems to contain oil in solution.

* Berzelius says at 45°. This is 113° Fahrenheit, if Celcius' thermometer be meant, as is probable. If it be Reaumur's, the melting point of marrow is 133° Fahrenheit.

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The charry matter in the retort amounts to 0·05 of the marrow distilled. It is dark brown, heavy and brilliant. It is incinerated with difficulty, and leaves an ash consisting of phosphate of lime, carbonate of lime, and some soda.

Action of acids.

5. Concentrated sulphuric acid dissolves marrow without the assistance of heat. The solution has the appearance of a brown syrup; and when the acid is diluted with water the marrow separates unaltered. When heat is applied, the acid decomposes the marrow and forms a resinous coal.

Diluted nitric acid digested in marrow, in a moderate heat, renders it yellow, and gives it more consistence, and the smell of old bones. Concentrated nitric acid dissolves marrow without the assistance of heat, and the marrow is not precipitated by the addition of water.

6. Marrow combines with alkalies and forms soap. Boiling alcohol and ether dissolve a small portion of it, which precipitates again as the solution cools.

Constituents.

Marrow, from the thigh bone of an ox, was found by Berzelius to be composed of the following substances:

Pure marrow	0·96
Skins and blood vessels	0·01
Albumen, Gelatine, Extractive, Peculiar matter, Water	0·03
	1·00

From the preceding detail it appears, that pure marrow is a species of fixed oil, possessing peculiar properties, and approaching somewhat to butter in its nature. But

t differs considerably in its appearance in different parts f the body, owing chiefly, in all probability, to a reater or smaller mixture of blood. Chap. II.

SECT. VIII.

OF HAIR AND FEATHERS.

THESE substances cover different parts of animals, and re obviously intended by Nature to protect them from he cold. For this, their softness and pliability, and he slowness with which they conduct heat, render hem peculiarly proper.

1. *Hair* is usually distinguished into various kinds, Varieties. ccording to its size and appearance. The strongest nd stiffest of all is called *bristle*: of this kind is the air on the backs of hogs. When remarkably fine, ft, and pliable, it is called *wool*; and the finest of all known by the name of *down*. But all these varieties semble one another very closely in their composition.

Hair appears to be a kind of tube covered with a Properties. ticle. Its surface is not smooth, but either covered ith scales or consisting of imbricated cones. Hence e roughness of its feel, and the disposition which it as to entangle itself, which has given origin to the ocesses of *felting* and *fulling*. It is constantly in- easing in length, being protruded from the roots, and

When the solution is filtered to get rid of this oil, the liquid which passes through is nearly colourless. Copious precipitates are formed in it by the infusion of nutgalls and oxymuriatic acid. Silver is blackened by it, and acetate of lead precipitated brown. Acids render it turbid, but the precipitate is redissolved by adding these liquids in excess. Though very much concentrated by evaporation, it does not concrete into a jelly. Chap. II.

Water containing only four *per cent.* of potash dissolves hair, while hydrosulphuret of ammonia is evolved. If the hair be black, a thick dark-coloured oil, with some sulphur and iron, remains undissolved; if the hair be red, there remains a yellow oil, with some sulphur and an atom or two of iron. When acids are dropt into this solution, they throw down a white matter soluble in an exces of acid.

Sulphuric and muriatic acids become red when first poured on hair, and gradually dissolve it. Nitric acid turns hair yellow and dissolves it, while an oil separates, which is red or black according to the colour of the hair dissolved. The solution yields a great deal of oxalic acid, and contains, besides, bitter principle, iron, and sulphuric acid. Oxymuriatic acid first whitens hair, and then reduces it to a substance of the consistence of turpentine, and partly soluble in alcohol.

Colouring matter.

When alcohol is digested on black hair, it extracts from it two kinds of oil. The first, which is white, subsides in white shining scales as the liquor cools; the second is obtained by evaporating the alcohol. It has a greyish green colour, and at last becomes solid. From red hair alcohol likewise separates two oils; the first white as from black hair, and the other as red as blood. When the red hair is deprived of this oil, it

Book V. becomes of a chesnut colour. Hence its red colour is obviously owing to the red oil.

When hair is incinerated, it yields iron and manganese, phosphate, sulphate, and carbonate of lime, muriate of soda, and a considerable portion of silica. The ashes of red hair contain less iron and manganese: those of white hair still less; but in them we find magnesia, which is wanting in the other varieties of hair. The ashes of hair do not exceed 0·015 of the hair.

From the preceding experiments of Vauquelin, we learn that black hair is composed of the nine following substances:

Constituents.

1. An animal matter, constituting the greatest part
2. A white solid oil, small in quantity
3. A greyish green oil, more abundant
4. Iron; state unknown
5. Oxide of manganese
6. Phosphate of lime
7. Carbonate of lime, very scanty
8. Silica
9. Sulphur

The colouring matter of hair appears from Vauquelin's experiments to be an oil. The oil is blackish green in black hair, red in red hair, and white in white hair. Vauquelin supposes that sulphureted iron contributes to the colour of dark hair; and ascribes to the presence of an excess of sulphur the property which white and red hair have of becoming black with the oxides of the white metals. The sudden change of colour in hair from grief, he thinks, is owing to the evolution of an acid *.

* Nicholson's *Jour.* xv. 241.

uquelin considers the animal matter of which hair iefly composed as a variety of inspissated mucus; ome of its properties, especially its copious preci- ion by tannin, do not well agree with that suppo- . It seems to approach more closely to coagula- lbumen, as Hatchett has shown.

Wool.

ool has not yet been subjected to a rigid examina- but from the experiments made on it by Berthol- here is reason to conclude that its chemical quali- o not differ much from those of hair. When grow- pon the sheep it is enveloped in a kind of soapy r, which protects it from the attack of insects, and h is afterwards removed by scouring. Vauquelin ately examined this matter, and found it to consist e following ingredients: 1. A soap of potash; 2. onate of potash; 3. A little acetate of potash; 4. ; 5. A very little muriate of potash; and, 6. An l matter *.

Feathers.

Feathers seem to possess very nearly the same pro- s with hair. Mr Hatchett has ascertained that the is composed chiefly of coagulated albumen. Though rs were boiled for a long time in water, Mr Hatch- uld observe no traces of gelatine.

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* *Ann. de Chim.* xlvii. 267.

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SECT. IX.

OF SILK.

Origin. SILK is the production of different species of caterpillars. The *phalena bombyx* is most commonly propagated for that purpose in Europe; but the *phalena atlas* yields a greater quantity. A similar substance indeed is yielded by the greater number of the tribe of caterpillars. It is found inclosed in two small bags, from which it is protruded in fine threads to serve the insect for a covering during its crysalis state. The webs of spiders are obviously of the same nature with silk; though their fibres, at least in this country, are finer and weaker. Reaumur and other naturalists ascertained, that the larger species of spiders spun cocoons sufficiently strong to be manufactured, and that the produce was neither inferior in beauty nor in strength to the silk of the silkworm. Attempts were made in consequence to establish a manufactory of this new kind of silk; but it was soon found that the spiders could not be made to work in concert. They attacked and devoured each other without mercy, till the whole colony was exterminated to a single individual.

Spiders' web

History. The silkworm is a native of China, and feeds on the leaves of the white mulberry. That industrious nation was acquainted with the manufacture of silk from the most remote ages; but it was scarcely known in Eu-

before the time of Augustus. Its beauty attracted attention of the luxurious Romans; and after the ninate reign of Elagabalus, it became a common le of dress. It was brought from China at an enor- s expense, manufactured again by the Phenicians, sold at Rome for its weight of gold. In the reign istinian this commerce was interrupted by the con- ts of the Scythian tribes, and all attempts to pro- it failed, till two Persian monks had the address nvey some of the eggs of the insect from China to tantinople, concealed in the hollow of a cane. They hatched, and the breed carefully propagated. This ened in 555; and some years after we find that Greeks understood the art of procuring and ma- cturing silk as well as the Orientals. Roger, king of y, brought the manufacture to that island in 1130, bly carrying off the weavers from Greece, and set- them in Sicily. From that island the art passed Italy, and thence into France: and the revocation e edict of Nantz established the manufactory of in Britain.

Chap. II.

lk, as spun by the animal, is in the state of fine ds, varying in colour from white to reddish yel- It is very elastic, and has considerable strength, consider its small diameter. It is covered with rnish, to which its elasticity is owing. This var- is soluble in boiling water; but alcohol does not pon it. Hence it has been compared to a gum, gh it approaches much nearer to gelatine; since nollet has shown that it is precipitated by tannin by muriate of tin. It differs, however, from gela- in several particulars. Alum throws it down of ty white, sulphate of copper of a dark brown, and

Varnish.

Book V. sulphate of iron of a brown colour *. When the water is evaporated, the varnish is obtained of a black colour, brittle, and of a shining fracture. Its weight is nearly one-third of the raw silk from which it was extracted. It may be separated from silk by soap as well as water, and the soap leys containing it soon putrefy †. Roard has lately published a set of experiments on this matter. It amounts to 23 *per cent.* of the silk. It is brittle and hard like resins; when pounded its colour is reddish yellow. It has the taste and odour of extractive. It does not melt when heated. It dissolves in five times its weight of water. The solution has a brown colour, but when diluted with water becomes golden yellow. When exposed to the air in that state it becomes greenish, is decomposed, and exhales the odour of putrid animal matter. The liquid froths like soap leys. Sulphuric and muriatic acids deepen its colour; nitric acid converts it into a fine yellow; sulphurous acid brightens the colour, and makes it greenish yellow. Alcohol scarcely acts upon it. Oxymuriatic acid throws down a copious white precipitate, which becomes reddish in the air, is no longer soluble in water, but is very soluble in alcohol. Alkalies produce no effect upon this substance. Infusion of nutgalls occasions a copious precipitate ‡. These properties show us that this substance is of a peculiar nature.

Resin. Besides the varnish, silk contains another substance, to which it owes its yellow colour. This substance possesses the properties of *resin*. It is yellow, soluble in alcohol, and in a mixture of alcohol and muriatic a-

* Berthollet. † Ibid. ‡ *Ann. de Chim.* lxv. 59.

cid. Baumé has ascertained, that by this last mixture it may be separated completely, and the silk deprived of it assumes a fine white colour *. This matter melts at 86°. Its colour is reddish brown when in lumps, but greenish yellow when divided. It has a strong smell, owing to a volatile oil which it contains. When exposed to the light it becomes white. It is insoluble in water but very soluble in alcohol, in the alkaline solutions and in soap †.

Roard has shown that raw silk contains also a portion of wax, which is dissolved by boiling alcohol, and by alkaline or soapy solutions. It is white and precipitates as the alcohol cools. Silk contains about $\frac{1}{100}$th of its weight of wax, while the resinous colouring matter amounts to about $\frac{1}{60}$th of its weight ‡.

Properties of silk.

The properties of silk itself have been but imperfectly examined. It is not acted on by water or alcohol, has no taste, and is but imperfectly combustible; though fire rapidly blackens and decomposes it. When distilled, it yields, according to Neumann, an uncommonly great proportion of ammonia.

The fixed alkalies dissolve it by the assistance of heat; and it is not unlikely that they form with it an animal soap.

It is dissolved likewise by sulphuric and muriatic acids, and by nitric acid. By the action of this last acid, Berthollet obtained from silk some oxalic acid, and a fatty matter which swam on the surface of the solution. By a similar treatment, Welter obtained fine

* *Ann. de Chim.* xvii. 156. † Roard, Ibid. lxv. 61. ‡ Ibid.

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yellow crystals, very combustible, to which he gave the name of *yellow bitter principle*.

Silk is very little susceptible of putrefaction. Dr Wilson of Falkirk informs us, that a ribbon was lately found in the churchyard of that town wrapt round the bone of the arm. It was uninjured though it had lain eight years in the earth *. We know, at the same time, that when silk is kept in a damp place it *rots* (to use the common language) in a much shorter period.

Spiders' web.

Cadet has lately published a chemical analysis of spiders' webs, the result of which, as these substances have a considerable analogy to silk, both in their properties and mode of being produced, may be mentioned here. He obtained from spiders' webs, by treating them with water and alcohol, and incineration, the following substances: 1. A brown extract soluble in water, and not altered by exposure to the air; 2. A resinous matter soluble in alcohol, and very deliquescent; 3. Alumina; 4. Sulphate of lime; 5. Carbonate of soda; 6. Muriate of soda; 7. Carbonate of lime; 8. Iron; 9. Silica †. He supposes, however, that some of the fixed matters obtained may have originated from accidental impurities mixed with the webs examined.

Having given the preceding account of the solids which compose animal bodies, I proceed next to the fluid which circulates through living bodies, namely *blood*; and to the various *secretions* formed from the

* Nicholson's *Jour.* ii. 222.

† Ibid. xi. 294.

blood, either in order to answer some important purpose to the animal, or to be evacuated as useless, that the blood thus purified may be more proper for answering the ends for which it is destined. Many of these substances have been examined with more care by chemists than the animal solids.

SECT. X.

OF BLOOD.

Properties of blood.

BLOOD is a well-known fluid which circulates in the veins and arteries of the more perfect animals. It is of a red colour, has a considerable degree of consistency, and an unctuous feel, as if it contained a quantity of soap. Its taste is slightly saline, and it has a peculiar smell.

The specific gravity of human blood is, at a medium, 1·0527 *. Mr Fourcroy found the specific gravity of bullock's blood, at the temperature of 60°, to be 1·056 †. The blood does not uniformly retain the same consistence in the same animal, and its consistence in different animals is very various. It is easy to see that its specific gravity must be equally various.

No substance has attracted a greater degree of attention than the blood. The number of philosophers who have devoted their time to develope its nature, and as-

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* Haller's *Physiology*, ii. 41. † *Ann. de Chim.* vii. 147.

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certain its properties, is immense. It was not, however, till towards the middle of the eighteenth century that much progress was made in its chemical analysis *. The prussic acid formed during its decomposition had been observed ; Hales had measured the gases exhaled during its distillation ; Menghini had demonstrated the presence of iron in it ; and several curious observations had been made upon its coagulation. But Rouelle junior was the first chemist who published a tolerably precise analysis of it. Since that time much additional information has been acquired by the experiments of Bucquet, Fourcroy, Deyeux, Parmentier, &c.

Spontaneous decomposition.

When blood, after being drawn from an animal, is allowed to remain for some time at rest, it very soon coagulates into a solid mass of the consistence of curdled milk. This mass gradually separates into two parts ; one of which is fluid, and is called *serum* ; the other, the coagulum, has been called *cruor*, because it alone retains the red colour which distinguishes blood. This separation is very similar to the separation of curdled milk into curds and whey.

The proportion between the cruor and serum of the blood varies much in different animals, and even in the same animal in different circumstances. The most common proportion is about one part of cruor to three parts of serum; but in many cases the cruor exceeds or falls short of this quantity ; the limits of the ratios of these substances to each other appear, from a comparison of the conclusions of most of those who have written ac-

* A very full account of every thing that had been done before that time may be found in the second volume of Haller's *Physiology*.

curately on the subject, to be 1 : 1 and 1 : 4; but the first case must be very rare indeed *.

The cause of this spontaneous decomposition of blood has not hitherto been ascertained. The coagulation takes place equally in close vessels and in the open air, whether the blood be allowed to cool, or be kept at the temperature at which it is when it issues from the animal; neither is the coagulation prevented by diluting it with water, as has been sufficiently proved by the experiments of Hewson, Hunter, Deyeux, and Parmentier.

Serum

1. The serum is of a light greenish yellow colour; it has the taste, smell, and feel of the blood, but its consistence is not so great. Its mean specific gravity is about 1·0287 †. It converts syrup of violets to a green, and therefore contains an alkali. On examination, Rouelle found that it owes this property to a portion of soda ‡. When heated to the temperature of 156° §, the serum coagulates, as Harvey first discovered ‖. It coagulates also when boiling water is mixed with it; but if serum be mixed with six parts of cold water, it does not coagulate by heat ¶. When thus coagulated, it has a greyish white colour, and is not unlike the boiled white of an egg **. If the coagulum be cut into small pieces, a muddy fluid may be squeezed from it, which has been termed the *serosity*. After the separation of this fluid, if the residuum be carefully washed in boiling water and examined, it will be found

* Haller's *Physiology*, ii. 47.

† Jurin, Ibid. p. 41.

‡ Dr Pearson considers the alkali in animal fluids as potash, and not soda.

§ Cullen.

‖ *De Gener. Anim.* p. 161.

¶ Fourcroy, *Ann. de Chim.* vii. 153.

** Ibid. 156.

Contains albumen,

to possess all the properties of coagulated *albumen*. The serum, therefore, contains a considerable proportion of albumen. Hence its coagulation by heat, and the other phenomena which albumen usually exhibits.

Gelatine,

If serum be diluted with six times its weight of water, and then boiled to coagulate the albumen, the liquid which remains after the separation of the coagulum, if it be gently evaporated till it becomes concentrated, and then be allowed to cool, assumes the form of a jelly, as was first observed by De Haen *. Consequently it contains *gelatine* †.

Sulphur,

If the coagulated serum be heated in a silver vessel, the surface of the silver becomes black, being converted into a sulphuret. Hence it is evident that it contains sulphur ‡; and Proust has ascertained that it is combined with ammonia in the state of a hydrosulphuret.

And salts.

If serum be mixed with twice its weight of water, and, after coagulation by heat, the albumen be separated by filtration, and the liquid be slowly evaporated till it is considerably concentrated, a number of crystals are deposited when the liquid is left standing in a cool place. These crystals, first examined by Rouelle, consist of carbonate of soda, muriate of soda, besides phosphate of soda and phosphate of lime. The soda exists in the blood in a caustic state, and seems to be combined with the gelatine and albumen. The carbonic acid combines with it during evaporation.

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* Fourcroy, *Ann. de Chim.* vii. 157.

† Dr Bostock repeated this experiment without success; hence it is probable that blood contains no gelatine.

‡ Deyeux and Parmentier, *Jour. de Phys.* xliv. 437.

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Thus it appears that the serum of the blood contains albumen, gelatine, hydrosulphuret of ammonia, soda, muriate of soda, phosphate of soda, and phosphate of lime. These component parts account for the coagulation occasioned in the serum by acids and alcohol, and the precipitation produced by tannin, acetate of lead, and other metallic salts.

Cruor contains fibrin,

2. The cruor, or *clot* as it is sometimes called, is of a red colour, and possesses considerable consistence. Its mean specific gravity is about 1·245 *. If this cruor be washed carefully by letting a small jet of water fall upon it till the water runs off colourless, it is partly dissolved, and partly remains upon the searce. Thus it is separated into two portions: namely, 1. A white, solid, elastic substance, which has all the properties of *fibrin*; 2. The portion held in solution by the water, which consists of the colouring matter, not however in a state of purity, for it is impossible to separate the cruor completely from the serum.

We are indebted to Bucquet for the first precise set of experiments on this last watery solution. It is of a red colour. Bucquet proved that it contained albumen and iron. Menghini had ascertained, that if blood be evaporated to dryness by a gentle heat, a quantity of iron may be separated from it by the magnet. The quantity which he obtained was considerable; according to him, the blood of a healthy man contains above two ounces of it. Now, as neither the serum nor the fibrin extracted from the cruor contains iron, it follows of course, that the water holding the colouring matter in solution must contain the whole of that metal.

* Jurin, Haller's *Physiology*, ii. 41.

Book V. Albumen, Soda.

This watery solution gives a green colour to syrup of violets. When exposed to the air, it gradually deposites flakes, which have the properties of albumen. When heated, a brown-coloured scum gathers on its surface. If it be evaporated to dryness, and then mixed with alcohol, a portion is dissolved, and the alcoholic solution yields by evaporation a residuum, which lathers like soap in water, and tinges vegetable blues green; the acids occasion a precipitate from its solution. This substance is a compound of albumen and soda. Thus we see that the watery solution contains albumen, iron, and soda.

Sub-phosphate of iron.

Fourcroy and Vauquelin have ascertained that the iron is combined with phosphoric acid, and in the state of sub-phosphate of iron; thus confirming an opinion which had been maintained by Sage, and announced as a fact by Gren. If the residuum obtained by evaporating the watery solution of the colouring matter of blood to dryness be burnt in a crucible, there will remain a deep red ferruginous substance, amounting to 0·045 of the blood employed. Nitric acid digested on this residuum dissolves a portion, which is phosphate of iron, and is precipitated white by ammonia, but assumes a red colour when treated with pure potash. When lime-water is poured into the potash employed, phosphate of lime precipitates. By this treatment they ascertained that $\frac{10}{16}$ths of the residuum consisted of sub-phosphate of iron. Now phosphate of iron is soluble in acids, but insoluble in water; when treated with pure alkalies, it loses a portion of its acid, assumes a red colour, and is converted into sub-phosphate. Hence it is evidently the soda of the blood which reduces it to that state, or at least maintains it in that state. Sub-

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phosphate of iron readily dissolves in albumen and in serum *.

3. When new-drawn blood is stirred briskly round with a stick or the hand, the whole of the fibrin collects together upon the stick, and in this manner may be separated altogether from the rest of the blood. The red globules, in this case, remain behind in the serum. It is in this manner that the blood is prepared for the different purposes to which it is put; as clarifying sugar, making puddings, &c. After the fibrin is thus separated, the blood no longer coagulates when allowed to remain at rest, but a spongy flaky matter separates from it, and swims on the surface †.

Action of heat on blood.

When blood is dried by a gentle heat, water exhales from it, retaining a very small quantity of animal matter in solution, and consequently having the odour of blood. Blood dried in this manner being introduced into a retort and distilled, there comes over, first a clear watery liquor, then carbonic acid gas, and carbonate of ammonia, which crystallizes in the neck of the retort; after these products there comes over a fluid oil, carbureted hydrogen gas, and an oily substance of the consistence of butter. The watery liquor possesses the property of precipitating from sulphate of iron a green powder: muriatic acid dissolves part of this powder, and there remains behind a little prussian blue. Consequently this watery liquor contains both an alkali and prussic acid ‡.

9216 grains of dried blood being put into a large

* Fourcroy, ix. 152.
† Fourcroy, *Ann. de Chim.* vii. 146.
‡ Ibid. 153.

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crucible, and gradually heated, at first became nearly fluid, and swelled up considerably, emitted a great many fetid fumes of a yellowish colour, and at last took fire and burned with a white flame, evidently owing to the presence of oil. After the flame and the fumes had disappeared, a light smoke was emitted, which affected the eyes and the nose; it had the odour of prussic acid, and reddened moist paper stained with vegetable blues. At the end of six hours, when the matter had lost five-sixths of its substance, it melted anew, exhibited a purple flame on its surface, and emitted a thick smoke. This smoke affected the eyes and nostrils, and reddened blue paper, but it had not the smell of prussic acid. When a quantity of it was collected and examined, it was found to possess the properties of phosphoric acid. The residuum amounted to 181 grains; it had a deep black colour and a metallic brilliancy; and its particles were attracted by the magnet. It contained no uncombined soda, though the blood itself, before combustion, contains it abundantly; but water extracted from it muriate of soda: part of the remainder was dissolved by muriatic acid, and of course was lime; there was besides a little silica, which had evidently been separated from the crucible. The iron had been reduced during the combustion *.

Component parts of blood.

Such are the properties of blood, as far as they have been hitherto ascertained by experiment. We have seen that it contains the following ingredients:

1. Water	3. Albumen
2. Fibrin	4. Gelatine

* Fourcroy, *Ann. de Chim.* vii. 151.

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drosulph. of ammonia	8. Muriate of soda
da	9. Phosphate of soda
b-phosphate of iron	10. Phosphate of lime

es benzoic acid, which has been detected by Proust.

But our knowledge of this singular fluid is by no s so complete as it ought to be; a more accurate sis would probably discover the presence of other nces, and enable us to account for many of the rties of blood which at present are inexplicable. would be of great consequence also to compare ier the blood of different animals, and of the same l at different ages, and to ascertain in what parti- they differ from each other. This would pro- throw light on some of the obscurest parts of the l economy. Very little progress has hitherto been in these researches. If we except the labours of lle, who obtained nearly the same ingredients, h in different proportions, from the blood of a variety of animals, the experiments of Fourcroy e blood of the human fœtus are almost the only of that kind with which we are acquainted.

Blood of the fœtus.

found that it differs from the blood of the adult ee things: 1. Its colouring matter is darker, and s to be more abundant; 2. It contains no fibrin, robably a greater proportion of gelatine than blood ults; 3. It contains no phosphoric acid *.

e examination of diseased blood, too, would be of consequence; because the difference of its proper- rom the blood of people in health might throw light on the nature of the disease.

* Fourcroy, *Ann. de Chim.* vii. 162.

SECT. XI.

OF MILK.

Milk is a fluid secreted by the female of all those animals denominated *mammalia*, and intended evidently for the nourishment of her offspring.

The milk of every animal has certain peculiarities which distinguish it from every other milk. But the animal whose milk is most made use of by man as an article of food, and with which, consequently, we are best acquainted, is the *cow*. Chemists, therefore, have made choice of cow's milk for their experiments. I shall at first confine myself to the properties and analysis of cow's milk, and afterwards point out in what respect the milk of other animals differs from it, as far at least as these differences have hitherto been ascertained.

Properties of milk.

Milk is an opaque fluid, of a white colour, a slight peculiar smell, and a pleasant sweetish taste. When newly drawn from the cow, it has a taste very different from that which it acquires after it has been kept for some hours. It reddens vegetable blues.

Its boiling and freezing points are nearly the same as those of water; but they vary a few degrees in different milks *. Milk is specifically heavier than wa-

* *Jour. de Phys.* xxxviii. 362.

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ter, and lighter than blood; but the precise degree cannot be ascertained, because almost every particular milk has a specific gravity peculiar to itself.

Spontaneous decomposition.

When milk is allowed to remain for some time at rest, there collects on its surface a thick unctuous yellowish coloured substance, known by the name of *cream*.

After the cream is separated, the milk which remains is much thinner than before, and it has a bluish white colour. If it be heated to the temperature of 100°, and a little *rennet*, which is water digested with the inner coat of a calf's stomach and preserved with salt, be poured into it, coagulation ensues; and if the coagulum be broken, the milk very soon separates into two substances; a solid white part, known by the name of *curd*, and a fluid part called *whey*. Thus we see that milk may be easily separated into three parts; namely, *cream*, *curd*, and *whey*.

1. CREAM is of a yellow colour, and its consistence increases gradually by exposure to the atmosphere. In three or four days it becomes so thick that the vessel which contains it may be inverted without risking any loss. In eight or ten days more, its surface is covered over with mucors and byssi, and it has no longer the flavour of cream, but of very fat cheese *. This is the process for making what in this country is called a *cream cheese*.

Cream

Cream possesses many of the properties of an oil. It is specifically lighter than water; it has an unctuous feel, stains clothes precisely in the manner of oil; and if it be kept fluid, it contracts at last a taste which is

* Parmentier and Deyeux, *Jour. de Phys.* xxxviii. 372.

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very analogous to the rancidity of oils *. When kept boiling for some time, a little oil makes its appearance, and floats upon its surface †. Cream is neither soluble in alcohol nor oils ‡. These properties are sufficient to show us that it contains a quantity of oil; but this oil is combined with a part of the curd, and mixed with some serum. Cream, then, is composed of a peculiar oil, curd, and serum. The oil may be easily obtained separate by agitating the cream for a considerable time. This process, known to every body, is called *churning*. After a certain time, the cream separates into two portions: one fluid, and resembling creamed milk; the other solid, and called *butter*.

Converted into butter.

Butter is of a yellow colour, possesses the properties of an oil, and mixes readily with other oily bodies. When heated to the temperature of 96° it melts, and becomes transparent; if it be kept for some time melted, some curd and water or whey separate from it, and it assumes exactly the appearance of oil §. But this process deprives it in a great measure of its peculiar flavour.

When butter is kept for a certain time, it becomes rancid, owing in a good measure to the presence of these foreign ingredients; for if butter be well washed, and a great portion of these matters separated, it does not become rancid nearly so soon as when it is not treated in this manner. It was formerly supposed that this rancidity was owing to the developement of a peculiar acid; but Parmentier and Deyeux have shown that no

* Parmentier and Deyeux, *Jour. de Phys.* xxxviii. 375. † Ibid. 374.
‡ Ibid. § Fourcroy, *Ann. de Chim.* vii. 170.

mena, it can scarcely be doubted that this gas is carbonic acid. Dr Young affirms, that during the churning there is an increase of temperature amounting to four degrees.

The affinity of the oil of cream for the other ingredients is such, that it never separates completely from them. Not only is curd and whey always found in the cream, but some of this oil is constantly found in creamed milk and even in whey: for it has been ascertained by actual experiment, that butter may be obtained by churning whey. 27 Scotch pints of whey yield at an average about a pound of butter *. This accounts for a fact well known to those who superintend dairies, that a good deal more butter may be obtained from the same quantity of milk, provided it be churned as drawn from the cow, than when the cream alone is collected and churned.

The butter-milk, as Parmentier and Deyeux ascertained by experiment, possesses precisely the properties of milk deprived of cream †.

Properties of curd.

2. Curd, which may be separated from creamed milk by rennet, has many of the properties of coagulated albumen. It is white and solid; and when all the moisture is squeezed out, it has a good deal of brittleness. It is insoluble in water; but pure alkalies and lime dissolve it readily, especially when assisted by heat; and when fixed alkali is used, a great quantity of ammonia is emitted during the solution. The solution of curd in soda is of a red colour, at least if heat be employed; owing probably to the separation of charcoal

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* *Mid-Lothian Report for* 1795.

† *Jour. de Phys.* xxxviii. 379.

Chap. II. Of cheese.

Curd, as is well known, is used in making *cheese*; and the cheese is the better the more it contains of cream, or of that oily matter which constitutes cream. It is well known to cheesemakers, that the goodness of it depends in a great measure on the manner of separating the whey from the curd. If the milk be much heated, the coagulum broken in pieces, and the whey forcibly separated, as is the practice in many parts of Scotland, the cheese is scarce good for any thing; but the whey is delicious, especially the last squeezed out whey, and butter may be obtained from it in considerable quantity:—a full proof that nearly the whole creamy part of the milk has been separated with the whey. Whereas if the milk be not too much heated (about 100° is sufficient), if the coagulum be allowed to remain unbroken, and the whey be separated by very slow and gentle pressure, the cheese is excellent; but the whey is almost transparent, and nearly colourless.

Good cheese melts at a moderate heat; but bad cheese, when heated, dries, curls, and exhibits all the phenomena of burning horn. From this it is evident, that good cheese contains a quantity of the peculiar oil which constitutes the distinguishing characteristic of cream; hence its flavour and smell. Proust has found in cheese an acid which he calls the *caseic* acid, to which he ascribes several of the peculiar properties of cheese †.

Coagulation of milk.

This resemblance of curd and albumen makes it probable that the coagulation of milk and of albumen depend upon the same cause. Heat, indeed, does not coa-

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* Parmentier and Deyeux, *Jour. de Phys.* xxxviii. 417.—Fourcroy, Ibid. p. 173.

† *Jour. de Phys.* lxiv. 107.

whey for some time boiling; a thick white scum gathers on the surface, which in Scotland is known by the name of *float whey*. When this scum, which consists of the curdy part, is carefully separated, the whey, after being allowed to remain at rest for some hours, to give the remainder of the curd time to precipitate, is decanted off almost as colourless as water, and scarcely any of the peculiar taste of milk can be distinguished in it. If it be now slowly evaporated, it deposites at last a number of white-coloured crystals, which are *sugar of milk*. Toward the end of the evaporation, some crystals of muriate of potash and of muriate of soda make their appearance *. According to Scheele, it contains also a little phosphate of lime †, which may be precipitated by ammonia.

Contains sugar of milk,

Salts.

The recent experiments of Fourcroy and Vauquelin, Thenard, and Bouillon La Grange, have added considerably to our knowledge of the constituents of whey. It always reddens vegetable blues, containing a portion of acetic acid. The lactic acid of Scheele is nothing else than this acid holding an animal matter in solution ‡. It contains likewise some phosphate of magnesia and phosphate of iron, as Fourcroy and Vauquelin have discovered §. Sulphate of potash, likewise, and a peculiar extractive matter, have been separated from it.

Milk is one of the few animal substances which may be made to undergo the vinous fermentation, and to af-

Milk capable of the vinous fermentation.

* Parmentier, *Jour. de Phys.* xxxviii. 457. † Scheele, ii. 61.
‡ Bouillon la Grange, *Ann. de Chim.* l. 272.—Vauquelin, Gehlen's *Jour.* iii. 456. § Gehlen, Ibid.

gave the name of *franchipann*. This substance, when the fire is increased, yields at first a transparent liquid, which becomes gradually more coloured; some very fluid oil comes over, then ammonia, an acid, and at last a very thick black oil. Towards the end of the process carbureted hydrogen gas is disengaged *. There remains in the retort a coal, which contains carbonate of potash, muriate of potash, and phosphate of lime, and sometimes magnesia, iron, and muriate of soda †.

Its composition.

Thus we see that cow's milk is composed of the following ingredients:

1. Water	7. Muriate of soda
2. Oil	8. Muriate of potash
3. Curd	9. Sulphate of potash
4. Extractive	10. Phosphate of lime
5. Sugar of milk	11. Phosphate of magnesia
6. Acetic acid	12. Phosphate of iron

The milk of all other animals, as far as it has hitherto been examined, consists nearly of the same ingredients: but there is a very great difference in their proportion.

Woman's milk.

WOMAN'S MILK has a much sweeter taste than cow's milk. When allowed to remain at rest for a sufficient time, a cream gathers on its surface. This cream is more abundant than in cow's milk, and its colour is usually much whiter. After it is separated, the milk is exceedingly thin, and has the appearance rather of

* Parmentier, *Jour. de Phys.* xxxvii. 368.

† *Mem. Med. Par.* 1787, p. 607.

1. It contains a much smaller quantity of curd.

2. Its oil is so intimately combined with its curd that it does not yield butter.

3. It contains rather more sugar of milk.

Parmentier and Deyeux ascertained that the quantity of curd in woman's milk increases in proportion to the time after delivery *. Nearly the same thing has been observed with respect to cow's milk.

Ass's milk.

ASS'S MILK has a very strong resemblance to human milk: It has nearly the same colour, smell, and consistence. When left at rest for a sufficient time, a cream forms upon its surface, but by no means in such abundance as in woman's milk. This cream, by very long agitation, yields a butter, which is always soft, white, and tasteless; and, what is singular, very readily mixes again with the butter-milk; but it may be again separated by agitation, while the vessel, which contains it, is plunged in cold water. Creamed ass's milk is thin, and has an agreeable sweetish taste. Alcohol and acids separate from it a little curd, which has but a small degree of consistence. The serum yields sugar of milk and muriate of lime †.

Ass's milk therefore differs from cow's milk in three particulars:

1. Its cream is less abundant and more insipid.

2. It contains less curd.

3. It contains more sugar of milk: the proportion is 35 : 80.

Goat's milk.

GOAT'S MILK, if we except its consistence, which is greater, does not differ much from cow's milk. Like

* Parmentier. *Jour. de Phys.* xxxviii. 422. † Ibid. 423.

that milk, it throws up abundance of cream, from which butter is easily obtained. The creamed milk coagulates just as cow's milk, and yields a greater quantity of curd. Its whey contains sugar of milk, muriate of lime, and muriate of soda *.

Ewe's milk.

Ewe's milk resembles almost precisely that of the cow. Its cream is rather more abundant, and yields a butter which never acquires the consistence of butter from cow's milk. Its curd has a fat and viscid appearance, and is not without difficulty made to assume the consistence of the curd of cow's milk. It makes excellent cheese †.

Mare's milk.

Mare's milk is thinner than that of the cow, but scarcely so thin as human milk. Its cream cannot be converted into butter by agitation. The creamed milk coagulates precisely as cow's milk, but the curd is not so abundant. The serum contains sugar of milk, sulphate of lime, and muriate of lime ‡.

SECT. XII.

OF EGGS.

Contents of eggs.

The eggs of fowls contain two distinct liquids; namely, the *white* and the *yolk*.

* Parmentier, *Jour. de Phys.* xxxviii. 425.
† Ibid. 428. ‡ Ibid. 431.

The white. Γhe white is a glary insipid liquid, often used as of varnish, and to clarify turbid liquors. For ost accurate experiments on the composition of quid we are indebted to Dr Bostock. It had been ered as almost pure albumen, but he has shown is of a more compound nature. When heated ulates ; but a small portion remains liquid, which, evaporated to dryness, leaves a residue possess-e properties of mucus. From the experiments of k, it follows that white of egg is composed of

Water	80·0
Albumen	15·5
Mucus	4·5
	100·0 *

s some traces of soda, of sulphureted hydrogen d of benzoic acid.

The yolk. Γhe yolk has a mild oily taste ; when boiled, it be- solid, and easily separates into small particles. If now heated for some time in a pan, it softens ; hen squeezed between the fingers, drops of oil . If put into linen in this state and pressed, an y be forced out. This oil is of a yellow colour sipid, unless too much heat has been employed in ing it. Its properties are those of *fixed* oil, or ra- f semifluid fat. Chandelier obtained this oil with- e assistance of heat †.

Contains oil,

Albumen, e residue, after the separation of the oil, possesses operties of albumen, though it is still a little co-

* Nicholson's *Jour.* xi. 246; and xiv. 142.

† *Jour. de Med.* xvi. 43.

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loured by the remains of the oil. Hence, when washed with water, a kind of emulsion is obtained. It is owing to the presence of albumen that the yolk hardens when heated.

And gelatine.

When this albumen is boiled in water, the liquid is said to separate a little gelatine. Thus it appears that the yolk consists of four constituents :

1. Water
2. Oil
3. Albumen
4. Gelatine.

The knowledge of its component parts enables us, without difficulty, to explain the changes produced upon the yolk by the action of different reagents.

Action of potash.

Mr Hatchett found that when yolk is boiled with potash, it forms a pale olive-coloured concrete animal soap, which, when dissolved in water, and saturated with muriatic acid, is thrown down in the state of fat. When burnt the yolk leaves a small residuum of phosphate of lime and phosphate of soda *.

When agitated with water, the yolk forms a white emulsion like milk. The principal use of the yolk is to serve for food to the chicken before it bursts the shell.

3. The membranes in which these two liquids are inclosed, consist most probably of coagulated albumen.

* Hatchett, *Phil. Trans.* 1800.

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SECT. XIII.

OF SALIVA.

History.

THE fluid secreted in the mouth, which flows in considerable quantity during a repast, is known by the name of *saliva*. All the properties of this liquor which had been observed by philosophers before the middle of the 18th century have been collected by Haller *: But since that time several additional facts have been related by Fourcroy, Du Tennetar, and Brugnatelli; and a very numerous set of experiments have been published by Mr Siebold in 1797, in his Treatise on the *Salivary System*.

Properties.

Saliva is a limpid fluid like water; but much more viscid: it has neither smell nor taste. Its specific gravity, according to Hamberger, is 1·0167 †; according to Siebold, 1·080. When agitated, it froths like all other adhesive liquids; indeed it is usually mixed with air, and has the appearance of froth.

It neither mixes readily with water nor oil ‡; but by trituration in a mortar it may be so mixed with water as to pass through a filter §. It has a great affinity for oxygen, absorbs it readily from the air, and gives it

* Haller's *Physiology*, vol. vi.

† Ibid. p. 52.

‡ Ibid. p. 34.

§ Fordice on *Digest.* p. 51.

When saliva is distilled in a retort, it froths very much: 100 parts yield 80 parts of water nearly pure, then a little carbonate of ammonia, some oil, and an acid, which perhaps is the prussic. The residuum amounts to about 1·56 part, and is composed of muriate of soda, phosphate of soda, and phosphate of lime *.

The acids and alcohol inspissate saliva; the alkalies disengage ammonia; oxalic acid precipitates lime; and the nitrates of lead, mercury, and silver, precipitate phosphoric and muriatic acids.

From these facts, it follows that saliva, besides water, which constitutes at least four-fifths of its bulk, contains the following ingredients:

1. Mucilage	4. Phosphate of soda
2. Albumen	5. Phosphate of lime
3. Muriate of soda	6. Phosphate of ammonia.

But it cannot be doubted that, like all the other animal fluids, it is liable to many changes from disease, &c. Brugnatelli found the saliva of a patient labouring under an obstinate venereal disease impregnated with oxalic acid †.

The concretions which sometimes form in the salivary ducts, &c. and the tartar or bony crust which so often attaches itself to the teeth, are composed of phosphate of lime ‡.

Saliva of the horse.

Such are the properties of human saliva. The saliva of the horse was analysed by Hapel Delachenier in 1780. He collected 12 ounces of it in the space of 24 hours by puncturing the salivary duct. Its colour was

* Vorbeyen, Textor, Nuck, &c. as quoted by Haller, *Physiol.* vi. 55.—Fourcroy, ix. 365.

† *Jour. de Phys.* xxxiii. 215.

‡ Fourcroy, ix. 367.

quantities of it are usually found collected in the gall bladder.

History.

Great attention has been paid to this liquid by physicians; because the ancients were accustomed to ascribe a very great number of diseases, and even affections of the mind, to its agency. Several important observations were made on it by Boyle, Boerhaave, Verheyen, Ramsay, and Baglivi; and some facts have since been added to our chemical knowledge of bile by Maclurg and Fourcroy. But the most accurate chemical analyses were those of Cadet, published in the Memoirs of the French Academy for 1767, and of Van Bochante, published in 1778, till Thenard read his very ingenious experiments on it to the National Institute in 1805 *. To him we are indebted not only for the first accurate analysis of ox bile, which, being most easily procured in quantities, has usually been chosen as the subject of chemical researches; but likewise for an examination of human bile, and that of several of the inferior animals, and for a comparison of these liquids with ox bile.

I shall in the first place state the nature and properties of ox bile, and then give an account of the bile of other animals as far as it has been examined.

Properties of ox bile.

1. Ox bile is a liquid of a yellowish green and sometimes of a deep green colour. Its taste is very bitter, but at the same time sweetish. Its smell is feeble, but peculiar and disagreeable. It does not act on vegetable blues. Its consistence varies very much. Sometimes it is a thin mucilage; sometimes very viscid and gluti-

* *Mem. d'Arcueil*, i. 23. and 46.

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nous; sometimes it is perfectly transparent, and sometimes it contains a yellow coloured matter which precipitates when the bile is diluted with water.

The specific gravity of ox bile seems to vary, like that of all other animal fluids. According to Hartmann, it is 1·027 *; according to Thenard, 1·026 at the temperature of 43°. When strongly agitated, it lathers like soap; and for this reason, as well as from a medical theory concerning its use, it has been often called an *animal soap*.

Action of heat.

It mixes readily with water in any proportion, and assumes a yellow colour; but it refuses to unite with oil; when the two fluids are agitated together, the instant that they are left at rest the oil separates and swims on the surface †. Bile, however, dissolves a portion of soap readily, and is often employed to free cloth from greasy spots.

When distilled to dryness it becomes at first slightly muddy; then it froths violently, and a colourless liquid passes into the receiver, having a smell similar to that of bile, and slightly precipitating superacetate of lead. The residue in the retort, when well dried, amounts to from $\frac{1}{8}$th to $\frac{1}{9}$th of the whole. It has a greenish yellow colour, a very bitter taste, slightly deliquesces in the air, and is almost totally soluble in water and alcohol. When strongly heated it is decomposed, and gives the usual products of animal substances; only the proportion of oil is greater, and that of carbonate of ammonia smaller, than what is furnished by most ani-

* Haller's *Phys.* vi. 546.

† Ramsay, *Thesaur. Med. Edin.* ii. 459.—Maclurg, p. 10.

mal bodies. A voluminous charcoal remains behind containing soda and several saline bodies; namely, common salt, phosphate of soda, sulphate of soda, phosphate of lime, and some traces of oxide of iron. The soda does not exceed $\frac{1}{100}$th part of the bile.

When an acid is added to bile, even in a minute quantity, it acquires the property of reddening vegetable blues. The addition of a little more acid occasions a precipitate, and sulphuric acid occasions a greater precipitate than any other acid. This precipitate consists of a yellow coloured matter often visible in bile, and which is insoluble in water. It contains also a little resin which gives it a bitter taste. Acids do not throw down the whole resin from bile. Yet if the resin be dissolved in soda, it is readily precipitated by all the acids; a proof that the resin is not kept in solution in bile by soda.

Resin.

When superacetate of lead is poured into bile a copious white precipitate falls, consisting of the resin combined with the oxide of lead. The superacetate of commerce does not readily throw down the whole resin; but if eight parts of common sugar of lead and one part of litharge be united together by digestion in water, a salt is formed which readily throws down the whole of the resin. If the precipitate be treated with diluted nitric acid the lead is separated, and the resin remains behind in a state of purity. It is a green coloured, bitter tasted substance, possessing most of the properties of resins. It has been already described in the preceding Chapter. One hundred parts of bile contain about three parts of resin.

Picromel.

If acetate of lead be poured into bile thus deprived of its resin by the superacetate, a new and more copiou

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precipitate falls, consisting of the oxide of lead united to a peculiar substance, which gives bile most of its characters. This substance was first described in detail by Thenard, who has given it the name of *picromel*. The compound consisting of oxide of lead and picromel is soluble in acetic acid. If a current of sulphuretted hydrogen gas be passed through the solution, the lead is separated; and by filtering and evaporating the liquid to dryness, the picromel is obtained in a separate state. When bile, mixed with muriatic acid and filtered, is set aside for some months in an open vessel, I have seen the picromel separate of its own accord. It is a white solid substance in small globules. It has a sweet, and at the same time an acrid taste, and is often somewhat bitter from retaining a portion of the resin. It facilitates the solution of resin in water: three parts of picromel and one part of resin dissolve in water. The addition of soda facilitates the solution of the resin. Ox bile consists essentially of picromel, resin, and soda, united together, and dissolved in water. The picromel prevents the precipitation of the resin by acids, and it prevents the soda from leaving the resin and uniting with acids.

Constituents.

By evaporating a quantity of bile to dryness, calcining it, and proceeding in the usual way, Thenard ascertained the proportion of salts which it contained. The following was the result of his analysis of 800 parts of bile.

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700·0	water
24·0	resin
60·3	picromel
4·5	yellow matter
4·0	soda
2·0	phosphate of soda
3·2	muriate of soda
0·8	sulphate of soda
1·2	phosphate of lime
	oxide of iron, a trace
800·0	

The albumen, announced as a constituent of ox bile by Cadet * and Ramsay †, was not found by Thenard. There is no doubt, however, that various species of bile contains albumen. I have found it myself in human bile, and there is every reason to believe that it at least occasionally exists in ox bile.

Ox bile owes its colour, taste, and smell, in a great measure to its resinous constituent. This resin is a solid substance of a bitter taste and a green colour. When melted it becomes yellow. It is very soluble in alcohol and in alkalies. Water dissolves some traces of it at a boiling heat. When sulphuric acid is poured into this water the resin is precipitated, but none of the other acids have that effect.

The picromel is a white solid substance very soluble in water and alcohol, and precipitated by nitrate of mercury, the salts of iron, and the acetate of lead. With soda and resin it forms a triple compound not decomposed by acids, nor alkaline and earthy salts.

* *Mem. Par.* 1767, p. 340. † *Thesaur. Edin.* ii. 460.

The yellow matter is the substance to which bile owes its tendency to putrefaction. It is insoluble in water, but is dissolved by the fixed alkaline solutions, and is precipitated by acids.

Bile of other animals.

2. Such are the properties and the constituents of ox bile, as far as they have been examined by Thenard. From the experiments of the same chemist it appears, that the bile of the calf, the dog, the sheep, and the cat, resemble that of the ox exactly, both in their properties and their constituents *.

Of the sow.

3. The bile of the sow differs entirely from that of all these animals. It contains neither albumen, nor animal matter, nor picromel, but is merely a soap, as it contains a great quantity of resin and of soda, and is decomposed with facility by all the acids, even by vinegar. It contains traces also of several salts; but Thenard did not ascertain their nature †.

Of fowls.

4. The bile of the common hen, of the turkey, and the duck, has a good deal of resemblance to that of quadrupeds. But it differs in the following particulars: 1. It contains a considerable quantity of albumen; 2. The picromel has no sensible sweet taste, but is very acrid and bitter; 3. It contains very little soda; 4. The resin is not precipitated by common superacetate of lead; but superacetate, boiled with $\frac{1}{5}$th of its weight of litharge, occasions it to precipitate ‡.

Of fishes.

5. The bile of the thornback and salmon is yellowish white. When evaporated it leaves a matter which has a very sweet and slightly acrid taste. It appears to contain no resin. The bile of the carp and the eel is

* *Mem. d'Arcueil*, i. 48. † Ibid. p. 49. ‡ Ibid. p. 50.

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very green, very bitter, contains little or no albumen, but yields soda, resin, and a sweet acrid matter similar to that which may be obtained from salmon bile *.

Human bile.

6. Human bile differs considerably from that of all other animals examined. Its colour is sometimes green, sometimes yellowish brown; sometimes it is nearly colourless. Its taste is not very bitter. It is seldom completely liquid, but usually contains some yellow matter suspended in it. When evaporated to dryness it leaves a brown matter amounting to about $\frac{1}{11}$th of the original weight. When this matter is calcined it yields all the salts which are to be found in ox bile. All the acids decompose human bile, and throw down a copious precipitate consisting of albumen and resin. One part of nitric acid is capable of saturating 100 parts of bile. The superacetate of lead throws down the resin, and leaves nothing but a yellowish liquid consisting of the salts of bile, and some atoms of a peculiar animal matter, the nature of which was not ascertained. Thus it appears that human bile contains no picromel. The following were the proportions of these substances obtained by Thenard from 1100 parts of human bile:

Constituents.

1000·0 water
from 2 to 10 yellow insoluble matter
yellow matter in solution, a trace
42·0 albumen
41·0 resin
5·6 soda
4·5 phosphate of soda, sulphate of soda, muriate of soda, phosphate of lime, oxide of iron

* Mem. d'Arcueil, i. 53.

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The yellow matter is insoluble in water, alcohol, and oils, but soluble in alkalies, and precipitated in greenish brown flocks by acids. Muriatic acid scarcely dissolves it, but gives it a brownish green colour, and then it is exactly similar to the yellow matter of ox bile.

The resin is yellowish, very fusible and very bitter. It dissolves readily in alcohol, and is precipitated by the acids. It is nearly insoluble in water, though not altogether so *.

Such are the properties and constituents of all the different species of bile hitherto subjected to chemical examination.

SECT. XV.

OF THE CERUMEN OF THE EAR.

Cerumen is a viscid yellow-coloured liquid secreted by the glands of the auditory canal, which gradually becomes concrete by exposure to the air. For all the facts respecting its composition at present known, we are indebted to Fourcroy and Vauquelin, especially the last, who analysed a considerable portion of it.

Properties.

It has an orange-yellow colour and a bitter taste. When slightly heated upon paper, it melts, and stains

* Thenard, *Mem. d'Arcueil*, i. 53.

the paper like an oil; at the same time it emits a slightly aromatic odour. On burning coals it softens, emits a white smoke, which resembles that given out by burning fat; it afterwards melts, swells, becomes dark-coloured, and emits an ammoniacal and empyreumatic odour. A light coal remains behind.

When agitated in water, cerumen forms a kind of emulsion, which soon putrefies, depositing at the same time white flakes.

Contains albumen

Alcohol, when assisted by heat, dissolves $\frac{5}{8}$ of the cerumen; the $\frac{3}{8}$ which remain behind have the properties of albumen, mixed however with a little oily matter. When the alcohol is evaporated, it leaves a deep orange residuum of a very bitter taste, having a smell and a consistence analogous to turpentine. It melts when heated, evaporates in a white smoke without leaving any residuum, and in short resembles very strongly the *resin of bile*. Ether also dissolves this oily body; but it is much less bitter and much lighter coloured. When the albuminous part of cerumen is burnt, it leaves traces of soda and of phosphate of lime. From these facts Vauquelin considers cerumen as composed of the following substances:

And resin.

Composition.

1. Albumen	4. Soda
2. An inspissated oil	5. Phosphate of lime.
3. A colouring matter	

The presence of the colouring matter is inferred from the portion taken up by ether being less coloured than that taken up by alcohol *.

* Fourcroy, ix. 373.

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SECT. XVI.

OF TEARS AND MUCUS.

1. That peculiar fluid which is employed in lubricating the eye, and which is emitted in considerable quantities when we express grief by weeping, is known by the name of *tears*. For an accurate analysis of this fluid we are indebted to Messrs Fourcroy and Vauquelin. Before their dissertation, which was published in 1791, appeared, scarcely any thing was known about the nature of tears.

Properties.

The liquid called tears is transparent and colourless like water ; it has scarcely any smell, but its taste is always perceptibly salt. Its specific gravity is somewhat greater than that of distilled water. It gives to paper stained with the juice of the petals of mallows or violet a permanently green colour, and therefore contains a fixed alkali *. It unites with water, whether cold or hot, in all proportions. Alkalies unite with it readily, and render it more fluid. The mineral acids produce no apparent change upon it †. Exposed to the air, this liquid gradually evaporates, and becomes thicker. When nearly reduced to a state of dryness, a number of cubic crystals form in the midst of a kind of mucilage. These crystals possess the properties of muriat

* Fourcroy and Vauquelin, *Jour. de Phys.* xxxix. 256. † Ibid. [illegible]

la ; but they tinge vegetable blues green, and there- Chap. II.
contain an excess of soda. The mucilaginous mat-
cquires a yellowish colour as it dries *.
is liquid boils like water, excepting that a consi-
ble froth collects on its surface. If it be kept a
ient time at the boiling temperature, $\frac{96}{100}$ parts of
iporate in water, and there remain about ·04 parts
yellowish matter, which by distillation in a strong
yields water and a little oil: the residuum consists
ferent saline matters †.
hen alcohol is poured into this liquid, a mucilagi-
matter is precipitated in the form of large white
s. The alcohol leaves behind it, when evaporated,
s of muriate of soda and soda. The residuum which
ins behind, when inspissated tears are burnt in the
air, exhibits some traces of phosphate of lime and
phate of soda ‡.
us it appears that tears are composed of the fol-
g ingredients :

. Water	4. Soda
. Mucus	5. Phosphate of lime
. Muriate of soda	6. Phosphate of soda.

Composition.

e saline parts amount only to about 0·01 of the
e, or probably not so much.
e *mucus* contained in the tears has the property of Properties of the mucilage.
bing oxygen gradually from the atmosphere, and
coming thick and viscid, and of a yellow colour.
then insoluble in water, and remains long sus-
ed in it without alteration. When a sufficient
tity of oxymuriatic acid is poured into tears, a yel-

Fourcroy and Vauquelin, *Jour. de Phys.* xxxix. 256. † Ibid.
bid. 259.

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low flaky precipitate appears, absolutely similar to this inspissated mucilage. The oxymuriatic acid loses its peculiar odour; hence it is evident that it has given out oxygen to the mucilage. The property which this mucilage has of absorbing oxygen, and of acquiring new qualities, explains the changes which take place in tears which are exposed for a long time to the action of the atmosphere, as is the case in those persons who labour under a fistula lachrymalis *.

Mucus of the nose.

2. The MUCUS of the nose has also been examined by Fourcroy and Vauquelin. They found it composed of precisely the same ingredients with the tears. As this fluid is more exposed to the action of the air than the tears, in most cases its mucilage has undergone less or more of that change which is the consequence of the absorption of oxygen. Hence the reason of the greater viscidity and consistence of the mucus of the nose; hence also the great consistence which it acquires during colds, where the action of the atmosphere is assisted by the increased action of the parts †.

Of cavities.

3. As to the MUCUS which lubricates the alimentary canal, the trachea, the bronchiæ, the urethra, and all the different cavities of the body, nobody has hitherto subjected it to analysis, because it cannot be obtained in sufficient quantity. It is viscid, and no doubt contains a mucilaginous substance, similar to that contained in the saliva, the tears, and the mucus of the nose; as, like these liquids, it is liable to become much more thick by exposure to the air.

* Fourcroy and Vauquelin, *Jour. de Phys.* xxxix. 257.
† Ibid. p. 259.

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e matter expectorated from the lungs and bronchiæ t be supposed to be mucilaginous; but from the xperiments on it by Dr Pearson, who has examined h much care and ingenuity *, this does not appear the case. Dr Pearson distinguishes seven differ- inds of expectorated matter. 1. The jelly-like ransparent kind of a bluish hue, excreted in a state lth; 2. The thin mucilage-like transparent matter piously expectorated in bronchial catarrhs; 3. The opaque straw-coloured, or white and very tenaci- natter, coughed up in a great variety of bronchial ulmonary affections, especially in that of tubercles; triform matter, secreted without any division of nuity or breach of surface of the bronchial mem- , very commonly occurring in pulmonary con- tions; 5. The matter which consists of opaque l masses, together with transparent fluid; or the d sort above stated with nodules of the third and h kind; 6. Pus from the vomicæ of tubercles; s from vomicæ by simple inflammation of the and without tubercles.

Expectorated matter.

om the experiments of Dr Pearson, it appears he constituents of the first five of these species are y the same. The chief variation is in the propor- of the ingredients. They all consist of water hold- n solution a quantity of albumen or animal oxide)r Pearson terms it), coagulable by heat and by the chemical agents. This albumen is combined with h † which it neutralizes. This albumen sometimes

Composition.

* arson on *Expectorated matter*. *Phil. Trans.* 1809.

† Pearson thinks that the alkali in animal fluids is not soda, as has

amounts to the twelfth or even the tenth of the expectorated matter; and when smallest it is never less than $\frac{1}{47}$th. The usual proportion varies from $\frac{1}{16}$th to $\frac{1}{12}$th. The potash varies between $\frac{1}{5}$ and $\frac{3}{4}$ths of a part in 1000 of the expectoratedmatter.

Expectorated matter yields traces of sulphur, and perhaps also of phosphorus, and it contains the following saline substances: 1. Muriate of soda, varying from $1\frac{1}{2}$ to $2\frac{1}{2}$ in the 1000 of expectorated matter; 2. Phosphate of lime about $\frac{1}{2}$ a part in the 1000; 3. Ammonia united probably to phosphoric acid; 4. A phosphate probably of magnesia; 5. Carbonate of lime; 6. A sulphate; 7. Vitrifiable matter probably silica; 8. Oxide of iron. The whole of these last six substances scarcely amounts to one part in the 1000 of expectorated matter.

The proportion of saline matter and of albumen present in expectorated matter varies much in different circumstances. The thicker it is in general the smaller is the quantity of saline matter; whereas when very thin it is often impregnated with salts, especially with muriate of soda to a great degree, and tastes distinctly salt and hot.

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hitherto been supposed, but potash. He has found this to be the case in blood, dropsy fluid, pus, liquid from blisters, urine, and mucus of the nose.

SECT. XVII.

LIQUOR OF THE PERICARDIUM.

[...]is is a liquor which lubricates the heart. It has [...]n lately examined by Dr Bostock, having been ob[...]ed from the pericardium of a boy who had died sud[...]ly *.

[...] had the colour and appearance of the serum of blood. Evaporated to dryness, it left a residue a[...]nting to $\frac{1}{11}$th of its weight. When exposed to the [...] of boiling water, it became opaque and thready. [...]as copiously precipitated by oxymuriate of mercu[...] before boiling; but when boiled, evaporated to dry[...], and redissolved, the solution was not affected by [...]muriate of mercury. These experiments show us [...] it contained albumen. When saturated with oxy[...]iate of mercury, infusion of galls produced no effect, [...]cating the absence of gelatine. It was copiously [...]cipitated by neutral acetate of lead, even after being [...]ed to dryness and the residue redissolved in water. [...]rate of silver indicated the presence of muriatic acid. Bostock, from his experiments, considers it as com[...]d of

* Nicholson's *Jour.* xiv. 147.

Water	92·0
Albumen	5·5
Mucus	2·0
Muriate of soda	0·5
	100·0

SECT. XVIII.

OF THE HUMOURS OF THE EYE.

Structure of the eye.

The eye is one of the most delicate and complicated organs in the body; at the same time its structure, and the uses of its parts, are better understood than almost any of the other instruments of sensation. It is composed of several concentric coats, which have not been chemically examined; but, from the experiments of Hatchett on similar substances, we may consider it as probable that they possess the properties of coagulated albumen. The internal part of the eye is chiefly filled with three transparent substances, which have been called *humours* by anatomists; namely, 1. The *aqueous humour*, immediately behind the cornea; 2. The *crystalline humour* or *lense*; and, 3. The *vitreous humour*, behind the lense, and occupying the greatest part of the eye. We knew scarcely any thing of the chemical properties of these humours till Mr Chenevix published an analysis of them in the Philosophical Transactions for 1802. Since that time an analysis of them has likewise been published by Nicholas *.

* *Ann. de Chim.* liii, 307.

I. Most of the experiments of Chenevix were made upon the eyes of sheep, as most easily procured. He afterwards tried the properties of humours from the eyes of other animals.

Eye of sheep.

1. The aqueous humour of the eye of the sheep is a clear transparent liquid like water, which has very little smell or taste when fresh. Its specific gravity is 1·0090 at the temperature of 60°.

Aqueous humour.

It scarcely alters vegetable blues when fresh *. When exposed to the air it evaporates slowly, and becomes slightly putrid. When boiled a very slight coagulum is formed. When 100 parts are evaporated to dryness, they leave eight parts of residuum. Tannin occasions a precipitate in it both before boiling and after it. Nitrate of silver occasions a precipitate of muriate of silver; but no precipitate is produced by other metallic salts. Hence it appears that the aqueous humour is water slightly impregnated with the following substances:

1. Albumen
2. Gelatine
3. Muriate of soda.

For Mr Chenevix found that the muriatic acid was in combination with soda. Nicholas has likewise detected a little phosphate of lime in it.

2. The vitreous matter possesses the very same properties as the aqueous; even its specific gravity is the same, or only a very little greater.

Vitreous humour.

3. The crystalline lense is solid: densest in the centre, and becoming less solid towards the circumference.

Lense.

* Nicholas found that it turned paper stained with the petals of the mallow to green.

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It is composed of concentric coats, and is transparent. Its specific gravity is 1·1000. When fresh it has little taste. It putrefies very rapidly.

It is almost completely soluble in water. The solution is partly coagulated by heat, and gives a copious precipitate with tannin both before the coagulation and after it. It gives no traces of muriatic acid. Hence it is composed of albumen and gelatine united to water. According to Nicholas, the quantity of gelatine diminishes as we approach the centre of the lense, where it is very small. He detected phosphate of lime likewise in every part of the lense.

Human eye.

II. The humours of the human eye are composed of the same ingredients as those of the sheep; the only perceptible difference consists in their specific gravity. The specific gravity of the human aqueous and vitreous humours is 1·0053; that of the crystalline 1·0790.

Eye of oxen.

III. The humours of the eyes of oxen resemble those of the sheep in their composition. The specific gravity of the aqueous and vitreous humours is 1·0088; that of the crystalline 1·0765.

From these three sets of experiments Mr Chenevix has drawn, as a probable conclusion, that the difference between the density of the aqueous and crystalline humours, and that of the crystalline, is in the inverse ratio of the diameter of the eye, taken from the cornea to the optic nerve.

The crystalline of the ox weighed 30 grains. When the whole of it was pared away except the six grains in the centre, the specific gravity was found to be 1·194 *.

* See *Phil. Trans.* 1801, and *Phil. Mag.* xvi. 268.

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Eye of birds.

IV. Mr Chenevix, in his paper, makes no mention of the eyes of birds; but Mr Davy published an abstract of it in the first volume of the Journal of the Royal Institution. He there states that Mr Chenevix found the humours of the eyes of birds composed of the same constituents as the eyes of other animals; but that he found at the same time the specific gravity of the vitreous humour in these animals greater than the specific gravity of the crystalline *.

SECT. XIX.

OF SINOVIA.

WITHIN the capsular ligament of the different joints of the body there is contained a peculiar liquid, intended evidently to lubricate the parts, and to facilitate their motion. This liquid is known among anatomists by the name of *sinovia*.

Whether it be the same in different animals, or even in all the different joints of the same animal, has not been determined, as no accurate analysis of the sinovia of different animals has been attempted. The only analysis of sinovia which has hitherto appeared is that by Mr Margueron, which was published in the 14th volume of the *Annales de Chimie*. He made use of sinovia obtained from the joints of the lower extremities of oxen.

* *Jour. of the Royal Instit.* i. 297.

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Sinovia of the ox.

The sinovia of the ox, when it has just flowed from the joint, is a viscid semitransparent fluid, of a greenish white colour, and a smell not unlike frog-spawn. It very soon acquires the consistence of jelly; and this happens equally whether it be kept in a cold or a hot temperature, whether it be exposed to the air or excluded from it. This consistence does not continue long; the sinovia soon recovers again its fluidity, and at the same time deposites a thready-like matter *.

Sinovia mixes readily with water, and imparts to that liquid a great deal of viscidity. The mixture froths when agitated; becomes milky when boiled, and deposites some pellicles on the sides of the dish; but its viscidity is not diminished †.

Contains albumen.

When alcohol is poured into sinovia, a white substance precipitates, which has all the properties of albumen. One hundred parts of sinovia contain 4·52 of albumen. The liquid still continues as viscid as ever; but if acetic acid be poured into it, the viscidity disappears altogether, the liquid becomes transparent, and deposites a quantity of matter in white threads, which possesses the following properties: 1. It has the colour, smell, taste, and elasticity of vegetable gluten. 2. It is soluble in concentrated acids and pure alkalies. 3. It is soluble in cold water; the solution froths. Acids and alcohol precipitate the fibrous matter in flakes. One hundred parts of sinovia contain 11·86 of this matter ‡.

And a fibrous matter.

When the liquid, after these substances have been separated from it, is concentrated by evaporation, it

* Margueron, *Ann. de Chim.* xiv. 124. † Ibid. p. 126.
‡ Ibid. p. 126, 130.

deposites crystals of acetate of soda. Sinovia, therefore, contains *soda*. Margueron found that 100 parts of sinovia contained about 0·71 of soda. Chap. II.

When strong sulphuric, muriatic, nitric, acetic, or sulphurous acid is poured into sinovia, a number of white flakes precipitate at first, but they are soon redissolved, and the viscidity of the liquid continues. When these acids are diluted with five times their weight of water, they diminish the transparency of sinovia, but not its viscidity; but when they are so much diluted that their acid taste is just perceptible, they precipitate the peculiar thready matter, and the viscidity of the sinovia disappears *.

And salts. When sinovia is exposed to a dry atmosphere, it gradually evaporates, and a scaly residuum remains, in which cubic crystals, and a white saline efflorescence are apparent. The cubic crystals are muriate of soda. One hundred parts of sinovia contain about 1·75 of this salt. The saline efflorescence is carbonate of soda †.

Sinovia soon putrefies in a moist atmosphere, and during the putrefaction ammonia is exhaled. When it is distilled in a retort, there comes over, first water, which soon putrefies; then water containing ammonia; then empyreumatic oil and carbonate of ammonia. From the residuum muriate and carbonate of soda may be extracted by lixiviation. The coal contains some phosphate of lime ‡.

* Margueron, *Ann. de Chim.* xiv. 127. † Ibid. p. 125.
‡ Ibid. p. 128.

SECT. XX.

OF SEMEN.

The peculiar liquid secreted in the testes of males, and destined for the impregnation of females, is known by the name of *semen*. The human semen and the melt of fresh water fishes alone have hitherto been subjected to chemical analysis. Nothing is known concerning the seminal fluid of other animals. 1. Vauquelin published an analysis of the human semen in 1791.

Properties. Semen, when newly ejected, is evidently a mixture of two different substances: the one fluid and milky, which is supposed to be secreted by the prostate gland; the other, which is considered as the true secretion of the testes, is a thick mucilaginous substance, in which numerous white shining filaments may be discovered *. It has a slight disagreeable odour, an acrid irritating taste, and its specific gravity is greater than that of water. When rubbed in a mortar it becomes frothy, and of the consistence of pomatum, in consequence of its enveloping a great number of air-bubbles. It converts paper stained with the blossoms of mallows or violets to a green colour, and consequently contains an alkali †.

As the liquid cools, the mucilaginous part becomes transparent, and acquires greater consistency; but in a-

* Vauquelin, *Ann. de Chim.* ix. 64. † Ibid. p. 65.

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bout twenty minutes after its emission, the whole becomes perfectly liquid. This liquefaction is not owing to the absorption of moisture from the air, for it loses instead of acquiring weight during its exposure to the atmosphere; nor is it owing to the action of the air, for it takes place equally in close vessels *.

Semen is insoluble in water before this spontaneous liquefaction, but afterwards it dissolves readily in it. When alcohol or oxymuriatic acid is poured into this solution, a number of white flakes are precipitated †. Concentrated alkalies facilitate its combination with water. Acids readily dissolve the semen, and the solution is not decomposed by alkalies; neither indeed is the alkaline solution decomposed by acids ‡.

Lime disengages no ammonia from fresh semen; but after that fluid has remained for some time in a moist and warm atmosphere, lime separates a great quantity from it. Consequently ammonia is formed during the exposure of semen to the air §.

Contains mucilage,

When oxymuriatic acid is poured into semen, a number of white flakes precipitate, and the acid loses its peculiar odour. These flakes are insoluble in water, and even in acids. If the quantity of acid be sufficient, the semen acquires a yellow colour. Thus it appears that semen contains a mucilaginous substance, analogous to that of the tears, which coagulates by absorbing oxygen. Mr Vauquelin obtained from 100 parts of semen six parts of this mucilage.

Phosphate of lime,

When semen is exposed to the air about the temperature of 60°, it becomes gradually covered with a trans-

* Vauquelin, *Ann. de Chim.* ix. 66.
† Ibid. p. 70.
‡ Ibid. p. 71.
§ Id. Ibid.

parent pellicle, and in three or four days deposites small transparent crystals, often crossing each other in such a manner as to represent the spokes of a wheel. These crystals, when viewed through a microscope, appear to be four-sided prisms, terminated by very long four-sided pyramids. They may be separated by diluting the liquid with water, and decanting it off. They have all the properties of phosphate of lime *. If, after the appearance of these crystals, the semen be still allowed to remain exposed to the atmosphere, the pellicle on its surface gradually thickens, and a number of white round bodies appear on different parts of it. These bodies also are phosphate of lime, prevented from crystallizing regularly by the too rapid abstraction of moisture. Mr Vauquelin found that 100 parts of semen contain three parts of phosphate of lime †. If at this period of the evaporation the air becomes moist, other crystals appear in the semen, which have the properties of carbonate of soda. The evaporation does not go on to complete exsiccation, unless at the temperature of 77°, and when the air is very dry. When all the moisture is evaporated, the semen has lost 0·9 of its weight; the residuum is semitransparent like horn, and brittle ‡.

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And soda.

When semen is kept in very moist air, at the temperature of about 77°, it acquires a yellow colour, like that of the yolk of an egg; its taste becomes acid, it exhales the odour of putrid fish, and its surface is covered with abundance of the *byssus septica* §.

Action of heat.

When dried semen is exposed to heat in a crucible, it melts, acquires a brown colour, and exhales a yellow

* Vauquelin, *Ann. de Chim.* ix. p. 67. and 73.
† Ibid. p. 68.
‡ Id. Ibid.
§ Id. Ibid.

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some muriate of ammonia, which exists naturally in the milt. When milt is dried slowly in a moderate heat it loses $\frac{4}{5}$ths of its weight, becomes yellow and brittle. When heated in a platinum crucible it softens and then melts, exhaling yellow vapours having the smell of animal oil. The charcoal formed contains a notable quantity of uncombined phosphoric acid, together with some phosphate of lime and phosphate of magnesia. As the acid did not exist in the milt it must have been formed during the combustion; and hence it follows that milt contains a notable quantity of phosphorus as a constituent.

Contains phosphorus.

123 parts of fresh milt, cautiously distilled in an earthen ware crucible, gradually heated to whiteness, furnished the following products: 1. A great deal of colourless water holding in solution carbonate of ammonia, a good deal of prussiate of ammonia, and traces of muriate of ammonia; 2. A transparent oil slightly yellow; 3. A fluid blood-red oil; 4. A thick blackish brown oil; 5. Crystals of carbonate and prussiate of ammonia; 6. A quantity of phosphorus; 7. A small quantity of carbonic acid and heavy inflammable air. The charcoal remaining in the retort amounts to $7\frac{1}{2}$ parts, and contains no disengaged phosphoric acid.

When milt is triturated in distilled water a white opaque liquid is obtained, which does not become transparent though passed through the filter. When the liquid is boiled an albuminous matter coagulates; and if the residuary liquid be evaporated sufficiently it gelatinizes; a proof that it contains gelatine. Alcohol digested on milt dissolves a substance which possesses the properties of animal soap. When it is separated the milt becomes dry and harsh to the feel; a proof that

Its specific gravity is 1·005. It gives a green colour to the tincture of violets, and yet it reddens very decidedly the tincture of turnsole. These two properties would indicate at once the presence of an acid and of an alkali. It froths considerably when agitated. On the application of heat it becomes opaque, and has then a great resemblance to milk diluted with a large quantity of water. At the same time it exhales the odour of boiled white of egg *. Chap. II.

Acids render it more transparent. Alkalies precipitate an animal matter in small flakes. Alcohol likewise produces a flaky precipitate, which, when collected and dried, becomes transparent and very like glue. The infusion of nutgalls produces a very copious brown coloured precipitate. Nitrate of silver occasions a white precipitate, which is insoluble in nitric acid, and consequently is muriate of silver †.

When slowly evaporated it becomes slightly milky, a transparent pellicle forms on its surface, and it leaves a residuum which does not exceed 0·012 of the whole. By lixiviating this residuum, and evaporating the ley, crystals of muriate and carbonate of soda may be obtained. The remainder, when incinerated, exhales a fetid and ammoniacal odour, resembling that of burning horn; the ashes consist of a small quantity of carbonate of soda, and of phosphate and carbonate of lime ‡.

Composition.

Thus we see that the liquor of the human amnios is composed of about

* *Ann. de Chim.* xxxiii. 271. † Ibid. ‡ Ibid. p. 272.

conjectured, that it is formed from the albumen of that liquid, which has undergone some unknown changes. It has been long known that the parts of a fœtus, which has lain for some time after it has been deprived of life in the uterus, are sometimes converted into a kind of fatty matter. It is evident that this substance, after it is deposited upon the skin of the fœtus, must preserve it in a great measure from being acted upon by the liquor of the amnios.

Liquor of the amnios of the cow.

2. The liquor of the amnios of the cow* has a viscidity similar to mucilage of gum arabic, a brownish red colour, an acid and bitter taste, and a peculiar odour, not unlike that of some vegetable extracts. Its specific gravity is 1·028. It reddens the tincture of turnsole, and therefore contains an acid. Muriate of barytes causes a very abundant precipitate, which renders it probable that it contains sulphuric acid. Alcohol separates from it a great quantity of a reddish coloured matter †.

When this liquid is evaporated, a thick frothy scum gathers on the surface, which is easily separated, and in which some white acid-tasted crystals may be discovered. By continuing the evaporation, the matter becomes thick and viscid, and has very much the look of honey. Alcohol boiled upon this thick matter, and filtered off, deposites upon cooling brilliant needleform crystals nearly an inch in length. These crystals may be obtained in abundance by evaporating the liquor of

* A minute account of the liquor amnii, and of the liquor alantoidis of the cow, has been published by Dzondi; for an abstract of which see Gehlen's *Jour.* Second Series, ii. 652.

† *Ann. de Chim.* xxxiii. 275.

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the amnios to a fourth part of its bulk, and then allowing it to cool. The crystals soon make their appearance. They may be separated and purified by washing them in a small quantity of cold water. These crystals are *amniotic* acid *.

If after the separation of this acid the liquor of the amnios be evaporated to the consistence of a syrup, large transparent crystals appear in it, which have all the properties of sulphate of soda. The liquid of the amnios of cows contains a considerable quantity of this salt.

Composition.

Thus it appears that the liquor of the amnios of cows contains the following ingredients:

1. Water
2. A peculiar animal matter
3. Acid
4. Sulphate of soda.

The animal matter possesses the following properties: It has a reddish brown colour and a peculiar taste; it is very soluble in water, but insoluble in alcohol, which has the property of separating it from water. When exposed to a strong heat it swells, exhales first the odour of burning gum, then of empyreumatic oil and of ammonia, and at last the peculiar odour of prussic acid becomes very conspicuous. It differs from gelatine in the viscidity which it communicates to water, in not forming a jelly when concentrated, and in not being precipitated by tannin. It must be therefore ranked among the very undefined and inaccurate class of *animal mucilages*. When burnt it leaves a very large coal, which is readily incinerated, and leaves a little white ashes,

* *Ann. de Chim.* xxxiii. 276.

composed of phosphate of magnesia, and a very small proportion of phosphate of lime *. Chap. II.

SECT. XXII.

OF ANIMAL POISONS.

Several animals are furnished with liquid juices of a poisonous nature, which when poured into fresh wounds occasion the disease or death of the wounded animal. Serpents, bees, scorpions, spiders, are well known examples of such animals. The chemical properties of these poisonous juices deserve peculiar attention; because it is only from such an investigation that we can hope to explain the fatal changes which they induce on the animal economy, or to discover an antidote sufficiently powerful to counteract their baneful influence. Unfortunately the task is difficult, and perhaps surpasses our chemical powers. For the progress already made in the investigation, we are indebted almost entirely to the labours of Fontana.

Poison of the viper

1. The poison of the viper is a yellow liquid, which lodges in two small vesicles in the animal's mouth. These communicate by a tube with the crooked fangs, which are hollow, and terminate in a small cavity. When the animal bites, the vesicles are squeezed, and

* *Ann. de Chim.* xxxiii. 278.

inflame till it has become black. These properties are similar to the properties of gum, and indicate the gummy nature of this poisonous substance. Fontana made a set of experiments on the dry poison of the viper, and a similar set on gum arabic, and obtained the same results. Chap. II.

From the late observations of Dr Russel, there is reason to believe that the poisonous juices of the other serpents are similar in their properties to those of the viper.

This striking resemblance between gums and the poison of the viper, two substances of so opposite a nature in their effects upon the living body, is a humiliating proof of the small progress we have made in the chemical knowledge of these intricate substances. The poison of the viper, and of serpents in general, is most hurtful when mixed with the blood. Taken into the stomach it kills if the quantity be considerable. Fontana has ascertained that its fatal effects are proportional to its quantity, compared with the quantity of the blood. Hence the danger diminishes as the size of the animal increases. Small birds and quadrupeds die immediately when they are bitten by a viper; but to a full-sized man the bite seldom proves fatal.

Ammonia proposed as an antidote.

Ammonia has been proposed as an antidote to the bite of the viper. It was introduced in consequence of the theory of Dr Mead, that the poison was of an acid nature. The numerous trials of that medicine by Fontana robbed it of all its celebrity; but it has been lately revived and recommended by Dr Ramsay as a certain cure for the bite of the rattlesnake *.

* *Phil. Mag.* xvii. The reader will find an interesting disserta-

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Venom of the bee and wasp,

2. The venom of the bee and the wasp is also a liquid contained in a small vesicle forced through the hollow tube of the sting into the wound inflicted by that instrument *. From the experiments of Fontana, we learn that it bears a striking resemblance to the poison of the viper. That of the bee is much longer in drying when exposed to the air than the venom of the wasp.

Of the scorpion,

3. The poison of the scorpion resembles that of the viper also. But its taste is hot and acrid, which is the case also with the venom of the bee and the wasp.

Of spiders.

4. No experiments upon which we can rely have been made upon the poison of the spider tribe. From the rapidity with which these animals destroy their prey, and even one another, we cannot doubt that their poison is sufficiently virulent †.

tion on the different remedies applied to the cure of the rattlesnake in the *Amer. Trans.* vol. iii. p. 100. by Dr Smith Barton. The observations of Fontana in his treatise on poisons deserve particular attention.

* See a curious account of the structure of the sting by Dr Hooke in his *Micrographia*.

† Dr Mead's romantic account of the bite of the tarantula will entertain the reader. See Mead on *Poisons*, p. 57.

Chap. II.

SECT. XXIII.

THE AIR CONTAINED IN THE SWIMMING BLADDERS OF FISHES.

History.

ANY fish are furnished with a bladder filled with air, neans of which they are supposed to rise or sink in water. When they wish to rise they are supposed lilate their air bladder; when they wish to sink compress it. Whether this be the use of the air lder of fishes is somewhat doubtful. Most fish have culiar depth at which they almost always remain. is the flat fish constantly affect the bottom of the sea, le there are others that as constantly affect the sur-. From the late observations of Biot it appears, when a fish is suddenly brought from a great depth ards the surface, the air bladder swells so much the fish cannot again sink; nay, it often bursts; the air making its way into the stomach, swells it and forces it into the mouth or œsophagus. The air h which these bladders is filled was first examined Dr Priestley in 1774. From his observations it aprs that it varies in its nature. The roach was the the air bladder of which he examined. At first he nd it filled with azote, but afterwards he got a mix- of oxygen and azote *.

* Priestley *On Air*, ii. 462.

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Fourcroy long after examined the air in the air bladder of the carp, and found it almost pure azote; and similar results were obtained by other chemists. But by far the most complete analysis of this kind of air has been lately made by Biot, while in Yviza and Formentera, two islands a little to the south of Majorca and Minorca. He was employed by the French government to prolong the meridian of France to the Balearean islands, and embraced the opportunity which presented itself to examine the air in the bladders of the different species of fish caught in the neighbourhood of these islands. Next season he returned to the same islands with Mr Laroche, who repeated and confirmed his preceding experiments *.

Experiments of Biot.

Biot found the air in the air-bladders a mixture of azotic and oxygen gas in very variable proportions. No traces of hydrogen gas could be detected; nor was there any sensible quantity of carbonic acid. The proportion of oxygen gas was very various, being sometimes very minute, and sometimes constituting almost the whole of the gas. The air bladders of those fish which live near the surface contained least oxygen gas, and the bladders of those which were brought up from a great depth contained the most. The following Table exhibits the proportion of oxygen in 100 parts of the air in the different fish examined.

Proportion of oxygen.

Names of the Fish.	Proportion of Oxygen.
Mugil cephalus (*Linn.*)............	Quantity insensible
Ditto	Ditto
Murœnophis helena (*Lacepede*)...	Very little

* Biot's Memoires are pri ted in the *Mem. D'Arcueil*, i. 252. and ii. 8

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Names of the Fish.	Proportion of Oxygen.
Sparus annularis (*Linn.*) female	0·09
Ditto male	0·08
Sparus sargus (*Linn.*) female	0·09
Ditto male	0·20
Holocentrus Marinus (*Lacepede*)	0·12
Labrus turdus (*Linn.*)	0·16
Sparus melanurus (*Linn.*)	0·20
Labrus turdus (*Var. Linn.*)	0·24
Sciæna nigra, female	0·27
Ditto male	0·25
Labrus turdus (*Linn.*) female	0·24
Ditto male	0·28
Sparus dentex (*Linn.*) female	0·40
Sphyrœna spet. (*Lacepede*)	0·44
Sparus argenteus	0·50
Sparus erythrinus	Much
Holycentrus gigas	0·69
Gadus merluccius (*Linn.*)	0·79
Trygla lyra (*Linn.*)	0·87

The depth at which the fish in the preceding table are caught increases gradually, as well as the proportion of oxygen, from the beginning to the end of the table. The last mentioned fish, the trygla lyra is always caught at a very great depth. The experiments of Laroche confirm the accuracy of this curious fact. The mean result, furnished by all the fishes taken at a depth greater than 150 feet, was 0·70 of oxygen; while the mean result, furnished by the fish caught at less depths, was 0·29. This superior purity is not owing to any superior purity in the air of the water of the sea at great depths. The air obtained from sea water, brought up from a great

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depth, yielded 0·265 of oxygen, while that from water taken at the surface was purer.

It is very remarkable that the air in the bladder of fishes, taken near the surface, should be almost pure azote. But this holds also with respect to fresh water fish. Thus Biot found the air in the air bladder of a carp to contain 0·03 of oxygen, while that of a tench contained 0·16; and Geoffroy and Vauquelin found the air in the air-bladder of pikes, loaches, and perches, to contain 0·05 of oxygen. Humboldt likewise found very little oxygen in the air bladder of the gymnotus electricus.

SECT. XXIV.

OF SWEAT.

A QUANTITY of matter is constantly emitted from the skin; this matter is invisible, and is distinguished by the name of *perspiration*. Several experiments were made by Lavoisier and Seguin to ascertain its amount. Mr Cruickshanks * made numerous trials to determine its nature, and it has been lately subjected to a chemical examination by Thenard †.

* Cruickshanks on *Insensible Perspiration*.
† *Ann. de Chim.* lix. 263.

Chap. II. Water.

1. Mr Cruickshanks put his hand into a glass vessel, and luted its mouth at his wrist by means of a bladder. The interior surface of the vessel became gradually dim, and drops of water trickled down. By keeping his hand in this manner for an hour, he collected 30 grains of a liquid, which possessed all the properties of pure water *. On repeating the same experiment at nine in the evening (thermometer 62°), he collected only 12 grains. The mean of these is 21 grains. But as the hand is more exposed than the trunk of the body, it is reasonable to suppose that the perspiration from it is greater than that from the hand. Let us therefore take 30 grains per hour as the mean; and let us suppose, with Mr Cruickshanks, that the hand is $\frac{1}{60}$th of the surface of the body: The perspiration in an hour would amount to 1880 grains, and in 24 hours to 43,200 grains, or seven pounds six ounces troy. This is almost double of the quantity ascertained by Lavoisier and Seguin. Hence we may conclude that more matter is perspired through the hand than the other parts of the body, provided Mr Cruickshanks's estimate of the ratio between the surface of the hand and body be not erroneous.

He repeated the experiment again after hard exercise, and collected in an hour 48 grains of water †. He found also, that this aqueous vapour pervaded his stocking without difficulty; and that it made its way through a shamoy leather glove, and even through a leather boot, though in a much smaller quantity than when the leg wanted that covering ‡.

* On *Insensible Perspiration*, p. 68. † Ibid. p. 70. ‡ Ibid. p. 82.

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Jurine found that air which had remained for some time in contact with the skin consisted almost entirely of carbonic acid gas *. The same conclusion may be drawn from the experiments of Ingenhousz and Milly †. Trousset has lately observed that air was separated copiously from a patient of his while bathing ‡.

Now it is evident that the carbonic acid gas which appeared during Mr Cruickshanks's experiment did not previously exist in the glass vessel; consequently it must have either been transmitted ready formed through the skin, or formed during the experiment by the absorption of oxygen gas, and the consequent emission of carbonic acid gas. The experiments of Mr Jurine do not allow us to suppose the first of these to be true; for he found that the quantity of air allowed to remain in contact with the skin did not increase. Consequently the appearance of the carbonic acid gas must be owing either to the emission of carbon, which forms carbonic acid gas by combining with the oxygen gas of the air, or to the absorption of oxygen gas, and the subsequent emission of carbonic acid gas; precisely in the same manner, and for the same reason, that these substances are emitted by the lungs. The last is the more probable opinion; but the experiments hitherto made do not enable us to decide.

3. An oily matter.

3. Besides water and carbon, or carbonic acid gas, the skin emits also a particular odorous substance. That every animal has a peculiar smell, is well known: the dog can discover his master, and even trace him to a

* *Encyc. Meth. Med.* i. 515.
† Ibid. p. 511.
‡ *Ann. de Chim.* xlv. 73.

wore clean flannel-waistcoats next their skin for ten days; the waistcoats had been first washed with soap, then in pure water, then in water acidulated with muriatic acid, and lastly in a great quantity of pure water. He steeped the waistcoats in hot distilled water, and thus separated from them the perspired matter. The liquid was put into a retort, and concentrated to the consistence of a syrup. The liquid which came over had a disagreeable smell, and reddened infusion of litmus. Kept in an open vessel it retained its transparency, but lost its odour. The residue in the retort had no smell. It was strongly acid, and tasted distinctly of common salt, while at the same time an acrid and hot flavour could be distinguished. When evaporated to dryness and strongly heated, the acid which it contained was dissipated or destroyed, and the residue consisted of common salt, charcoal, and minute traces of phosphate of lime, and oxide of iron. The same destruction of the acid took place if it was previously saturated with potash before it was heated to redness, and in that case the potash was converted into a carbonate. When saturated with an alkali, and distilled along with phosphoric acid, it yielded an acid which possessed all the characters of the acetic *.

5. Animal matter.

5. The small quantity of animal matter which Thenard found in the perspired matter, possessed characters which induced him to consider it as similar to gelatine in its nature.

Fourcroy and Vauquelin have ascertained that the scurf which collects on the skins of horses consists chief-

* Thenard, *Ann. de Chim.* lix. 263.

ly of phosphate of lime, and urea is even sometimes mixed with it.

Such are the constituents of *perspired matter*. Though the sweat has not been directly analysed, there is every reason to believe that it is composed of similar constituents.

SECT. XXV.

OF URINE.

History.

No animal substance has attracted more attention than urine, both on account of its supposed connection with various diseases, and on account of the very singular products which have been obtained from it. Mr Boyle, and the other chemists who were his contemporaries, were induced to attend particularly to this liquid, by the discovery of a method of obtaining phosphorus from it. Boerhaave, Haller, Haupt, Margraff, Pott, Rouelle, Proust, and Klaproth, successively improved the method of obtaining the phosphoric salts from urine, or added something to our knowledge of the component parts of these salts. Scheele added greatly to our knowledge of urine by detecting several new substances in it which had not been suspected. Cruickshanks has given us a very valuable paper on urine in the second edition of *Rollo's Diabetes*. Fourcroy and Vauquelin have lately published a very complete analysis of it; and Mr Proust has published another, no less ingenious,

in which he points out the existence of several substances which had been overlooked by other chemical philosophers.

Properties.

Fresh urine differs considerably in its appearance according to the state of the person and the time at which it is voided. In general, healthy urine is a transparent liquid of a light amber colour, an aromatic odour resembling that of violets, and a disagreeable bitter taste. Its specific gravity varies, according to Mr Cruickshanks, from 1·005 to 1·033. When it cools, the aromatic smell leaves it, and is succeeded by another, well known by the name of *urinous smell.* This smell is succeeded in two or three days by another, which has a considerable resemblance to that of sour milk. This smell gradually disappears in its turn, and is succeeded by a fetid alkaline odour.

Contains an acid,

1. Urine reddens paper stained with turnsole and with the juice of radishes, and therefore contains an acid. This acid has been generally considered as the phosphoric; but Thenard has shown that it is in reality the acetic *.

Phosphate of lime,

2. If a solution of ammonia be poured into fresh urine, a white powder precipitates, which has the properties of phosphate of lime. The presence of this substance in urine was first discovered by Scheele †. The phosphate of lime is obviously kept in solution by the acetic acid. Scheele affirms that it is most abundant in the urine of the sick. Berthollet has observed, that the urine of gouty people is more acid than that of people in perfect health. The average quantity of phos-

* *Ann. de Chim.* lix. 269.

† Scheele, i. 208.

phate of lime in healthy urine is, as Cruickshanks has ascertained, about $\frac{1}{900}$ of the weight of the urine *.

Phosphate of magnesia,

3. If the phosphate of lime precipitated from urine be examined, a little magnesia will be found mixed with it. Fourcroy and Vauquelin have ascertained that this is owing to a little phosphate of magnesia which urine contains, and which is decomposed by the alkali or lime employed to precipitate the phosphate of lime †.

Carbonic acid,

4. Proust informs us that carbonic acid exists in urine, and that its separation occasions the froth which appears during the evaporation of urine ‡. Fourcroy and Vauquelin, on the other hand, consider this acid as formed during the evaporation by the decomposition of the urea. The observations of Proust confirm those that had been made by Priestley and Percival.

Carbonate of lime,

5. Proust has observed, that urine kept in new casks deposites small crystals which effloresce in the air and fall to powder. These crystals possess the properties of carbonate of lime §. Hence we must conclude that urine contains carbonate of lime; a very extraordinary fact, if we reflect that acetic acid is also present.

Uric acid,

6. When fresh urine cools, it often lets fall a brick-coloured precipitate, which Scheele first ascertained to be crystals of uric acid. All urine contains this acid, even when no sensible precipitate appears when it cools. For, if a sufficient quantity of clear and fresh urine be evaporated to $\frac{1}{178}$ of its weight, a subtle powder pre-

* *Phil. Mag.* ii. 241.

† *Ann. de Chim.* xxxi. 66.—The same discovery had been previously made by Dr Wollaston. See his examination of calculi, *Phil. Trans.* 1797.

‡ *Ann. de Chim.* xxxvi. 260.

§ Ibid. p. 263.

cipitates to the bottom, and attaches itself in part very firmly to the vessel. This part may be dissolved in pure alkali, and precipitated again by acetic acid. It exhibits all the properties of uric acid *. The fact is, that the precipitate which usually falls when urine cools consists chiefly of phosphate of lime and uric acid. It may be dissolved in diluted nitric acid. If the solution be heated and evaporated to dryness, it assumes a fine rose colour if uric acid be present †. The proportion of uric acid varies considerably in urine. It crystallizes in small red prisms, partly on the surface, if urine be mixed with some nitric acid, and left exposed to the air. Indeed, from the late ingenious experiments of Dr Egan, we learn that all acids when mixed with urine throw down uric acid in crystals ‡.

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Rosacic acid,

7. During intermittent fevers, and especially during diseases of the liver, a copious sediment of a brick red colour is deposited from urine. This sediment contains the rosacic acid of Proust.

Benzoic acid,

8. If fresh urine be evaporated to the consistence of a syrup, and muriatic acid be then poured into it, a precipitate appears which possesses the properties of benzoic acid. Scheele first discovered the presence of benzoic acid in urine. He evaporated it to dryness, separated the saline part, and applied heat to the residuum. The benzoic acid was sublimed, and found crystallized in the receiver. The above method was first proposed by Fourcroy and Vauquelin §. By it very considerable quantities of benzoic acid may be obtained from the

* Scheele, i. 207.
† Cruickshanks.
‡ *Phil. Mag.* xxiii. 298.
§ *Ann. de. Chim.* xxxi. 62.

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urine of horses and cows, where it is much more abundant than in human urine. In human urine it varies from $\frac{1}{1000}$ to $\frac{1}{10000}$ of the whole *. Proust affirms that the acid obtained by Scheele's process is not the benzoic, but another possessed of similar properties; but differing in this circumstance, that nitric acid decomposes it, whereas it only whitens benzoic acid †.

Albumen and gelatine,

9. When an infusion of tannin is dropt into urine, a white precipitate appears, having the properties of the combination of tannin and albumen, or gelatine. Urine, therefore, contains albumen or gelatine. These substances had been suspected to be in urine, but their presence was first demonstrated by Seguin, who discovered the above method of detecting them. Their quantity in healthy urine is very small, often indeed not sensible. Cruickshanks found that the precipitate afforded by tannin in healthy urine amounted to $\frac{1}{120}$th part of the weight of the urine ‡. It is to these substances that the appearance of the *cloud*, as it is called, or the mucilaginous matter, which is sometimes deposited as the urine cools, is owing. In many diseases the quantity of these matters is very much increased. The urine of dropsical people often contains so much albumen, that it coagulates not only on the addition of acids, but even on the application of heat §. In all cases of impaired digestion, the albuminous part of urine is much increased. This forms one of the most conspicuous and important distinctions between the urine of those who enjoy good and bad health ‖.

* *Ann. de Chim.* xxxi. 63.
† Ibid. xxxvi. 273.
‡ *Phil. Mag.* ii. 243.
§ Cruickshanks, Ibid. 248.
‖ Fourcroy and Vauquelin, *Ann. de Chim.* xxxi. 61.

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10. If urine be evaporated by a slow fire to the consistence of a thick syrup, it assumes a deep brown colour, and exhales a fetid ammoniacal odour. When allowed to cool, it concretes into a mass of crystals, composed of all the component parts of urine. If four times its weight of alcohol be poured upon this mass, at intervals, and a slight heat be applied, the greatest part of it is dissolved. The alcohol, which has acquired a brown colour, is to be decanted off, and distilled in a retort in a sand heat, till the mixture has boiled for some time, and acquired the consistence of a syrup. By this time the whole of the alcohol has passed off, and the matter, on cooling, crystallizes in quadrangular plates which intersect each other. This substance is *urea*, which composes $\frac{9}{10}$ of the urine, provided the watery part be excluded. To this substance the taste and smell of urine are owing. It is a substance which characterizes urine, and constitutes it what it is, and to which the greater part of the very singular phenomena of urine are to be ascribed. Urea,

It may be detected by evaporating urine to the consistence of a syrup, and pouring into it concentrated nitric acid. Immediately a great number of white shining crystals appear in the form of plates, very much resembling crystallized boracic acid. These crystals are urea combined with nitric acid.

The quantity of urea varies exceedingly in different urines. In the urine voided soon after a meal, very little of it is to be found, and scarcely any at all in that which hysterical patients void during a paroxysm.

11. According to Fourcroy and Vauquelin, the colour of urine depends upon the urea: the greater the proportion of urea, the deeper the colour. But Proust Resin,

has detected a resinous matter in urine, similar to the resin of bile; and to this substance he ascribes the colour of urine. If urine, evaporated to the consistence of an extract, be mixed with sulphuric acid and distilled, this resin, he informs us, separates during the distillation. What is first obtained is soft, but the last portions are in a state of a dry powder. The consistence and colour of this resin resemble castor: it is very soluble in alcohol, and precipitated from its solution by water: but it is also soluble in water; and, according to Proust, is the resin of bile, somewhat modified by its passage through the urinary organs *.

Muriate of soda.

12. If urine be slowly evaporated to the consistence of a syrup, a number of crystals make their appearance on its surface: these possess the properties of muriate of soda. Urine therefore contains muriate of soda. It is well known that muriate of soda crystallizes in cubes; but when obtained from urine it has the form of octahedrons. This singular modification of its form is owing to the action of urea †. It has been long known that urine saturated with muriate of soda deposites that salt in regular octahedrons.

Phosphates of ammonia and of soda,

13. The saline residuum which remains after the separation of urea from crystallized urine by means of alcohol has been long known by the names of *fusible salt of urine* and *microcosmic salt*. Various methods of obtaining it have been given by chemists, from Boerhaave, who first published a process, to Rouelle and Chaulnes, who gave the method just mentioned. If this saline mass be dissolved in a sufficient quantity of hot water,

* *Ann. de Chim.* xxxvi. 274.

† Fourcroy and Vauquelin.

and allowed to crystallize spontaneously in a close vessel, two sets of crystals are gradually deposited. The lowermost set has the figure of flat rhombodial prisms; the uppermost, on the contrary, has the form of rectangular tables. These two may be easily separated by exposing them for some time to a dry atmosphere. The rectangular tables effloresce and fall to powder, but the rhomboidal prisms remain unaltered.

When these salts are examined, they are found to have the properties of phosphates. The rhomboidal prisms consist of phosphate of ammonia united to a little phosphate of soda; the rectangular tables, on the contrary, are phosphate of soda united to a small quantity of phosphate of ammonia. Urine, then, contains phosphate of soda and phosphate of ammonia.

Muriate of ammonia.

14. When urine is cautiously evaporated, a few cubic crystals are often deposited among the other salts; these crystals have the properties of muriate of ammonia. Now the usual form of the crystals of muriate of ammonia is the octahedron. The change of its form in urine is produced also by urea. This salt is obtained in greater abundance when the crystals of urea obtained from the alcohol solution are distilled *.

Sulphur.

15. When urine is boiled in a silver basin, it blackens the basin; and if the quantity of urine be large, small crusts of sulphuret of silver may be detached. Hence we see that urine contains sulphur. This sulphur exhales along with the carbonic acid when the urine putrefies; for the fumes which separate from

* Fourcroy and Vauquelin.

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urine in that state blacken paper stained with acetate of lead *.

Constituents.

Urine, then, contains the following substances:

1. Water
2. Acetic acid
3. Phosphate of lime
4. Phosphate of magnesia
5. Carbonic acid
6. Carbonate of lime
7. Uric acid
8. Rosacic acid
9. Benzoic acid
10. Albumen
11. Urea
12. Resin
13. Muriate of soda
14. Phosphate of soda
15. Phosphate of ammonia
16. Muriate of ammonia
17. Sulphur.

Substances occasionally present.

These are the only substances which are constantly found in healthy urine †; but it contains also occasionally other substances. Very often muriate of potash may be distinguished among the crystals which form during its evaporation. The presence of this salt may always be detected by dropping cautiously some tartaric acid into urine. If it contains muriate of potash, there will precipitate a little tartar, which may easily be recognized by its properties ‡.

Urine sometimes also contains sulphate of soda, and even sulphate of lime. The presence of these salts may be ascertained by pouring into urine a solution of muriate of barytes; a copious white precipitate appears, consisting of the barytes combined with phosphoric acid, and with sulphuric acid, if any be present. This precipitate must be treated with a sufficient quantity of

* Proust, *Ann. de Chim.* xxxvi. 258.

† Fourcroy and Vauquelin, Ibid. xxxi. 69.

‡ Cruickshanks, *Phil. Mag.* ii. 241.

muriatic acid. The phosphate of barytes is dissolved, but the sulphate of barytes remains unaltered *. Chap. II.

Putrefaction of urine.

No substance putrefies sooner, or exhales a more detestable odour, during its spontaneous decomposition, than urine; but there is a very great difference in this respect in different urines. In some, putrefaction takes place almost instantaneously as soon as it is voided; in others, scarcely any change appears for a number of days. Fourcroy and Vauquelin have ascertained that this difference depends on the quantity of gelatine and albumen which urine contains. When there is very little of these substances present, urine remains long unchanged; on the contrary, the greater the quantity of gelatine or albumen, the sooner does putrefaction commence. The putrefaction of urine, therefore, is in some degree the test of the health of the person who has voided it: for a superabundance of gelatine in urine always indicates some defect in the power of digestion †.

The rapid putrefaction of urine, then, is owing to the action of gelatine on urea. We have seen already the facility with which that singular substance is decomposed, and that the new products into which it is changed are, ammonia, carbonic acid, and acetic acid. Accordingly, the putrefaction of urine is announced by an ammoniacal smell. Mucilaginous flakes are deposited, consisting of part of the gelatinous matter. The phosphoric acid is saturated with ammonia, and the phosphate of lime, in consequence, is precipitated. Ammonia combines with the phosphate of magnesia, forms

* Fourcroy, *Ann. de Chim.* vii. 183.
† Id. Ibid. xxxi. 61.

the acids contained in urine are saturated with ammonia, and the gelatine and phosphate of lime precipitate *. Chap. II.

Such are the properties of human urine in a state of health: But this excretion is singularly modified by disease; and the changes to which it is liable have attracted the attention of physicians in all ages, because they serve in some measure to indicate the state of the patient, and the progress of the disease under which he labours. The following are the most remarkable of these changes that have been observed †. Changes in it by disease.

1. In *inflammatory* diseases the urine is of a red colour, and peculiarly acrid; it deposites no sediment on standing, but with oxymuriate of mercury it yields a copious precipitate. Inflammation.

2. During *jaundice* the urine has an orange yellow colour, and communicates the same tint to linen. Muriatic acid renders this urine green, and thus detects the presence of a little bile. Jaundice.

From the experiments of Fourcroy and Vauquelin, we learn that urine sometimes in these cases contains a substance analogous to the *yellow* acid which they formed by the action of nitric acid on muscular fibres ‡.

3. About the end of *inflammatory* diseases the urine becomes abundant, and deposites a copious pink-coloured sediment, composed of rosacic acid, a little phosphate of lime, and uric acid. End of inflammation.

4. During *hysterical* paroxysms the urine usually Hysteria.

* *Ann. de Chim.* xxxi. 55.

† See Cruickshanks, *Phil. Mag.* ii. 240.; and Fourcroy, x. 166.

‡ *Phil. Mag.* xxiii. 331.

Chap. II.

Urine of inferior animals.

ɪᴇ urine of other animals differs considerably from of man. For the analysis of the urine of quadru- hitherto made, we are chiefly indebted to Rouelle r. The following facts have been ascertained by chemist, and by the late experiments of Fourcroy Vauquelin, Brande, and Chevreul.

The horse.

The urine of the HORSE has a peculiar odour: af- xercise it is emitted thick and milky; at other it is transparent, but becomes muddy soon after nission. When exposed to the air, its surface be- s covered with a crust of carbonate of lime. It a green colour to syrup of violets, and has the stence of mucilage. The following are its consti- s, as estimated by Fourcroy and Vauquelin from experiments:

Carbonate of lime	0·011
Carbonate of soda	0·009
Benzoate of soda	0·024
Muriate of potash	0·009
Urea	0·007
Water and mucilage	0·940
	1·000 *

ie urine of the horse has been lately analysed by Brande. The salts which it contains are, according n, the following:

abetic urine by Nicolas, *Ann. de Chim.* xliv. 32.; the analysis of c urine by Sorg (Gehlen's *Jour.* vi. 9.), and by Dupuytren and rd (*Ann. de Chim.* lix. 41.)

Mem. de l'Instit. ii. 431.

Carbonate of lime
Carbonate of soda
Sulphate of soda
Muriate of soda
Benzoate of soda
Phosphate of lime

These saline substances amount to about $\frac{1}{11}$th of the urine *. The urine of the horse has been recently subjected to a new examination by Chevreul expressly to ascertain whether it contained phosphate of lime announced in it by Brande. His experiments confirmed those of Fourcroy and Vauquelin. The urine yielded no traces of phosphate of lime; but it contained magnesia and sulphate of potash, neither of which substances had been observed by Mr Brande †.

From the late experiments of Mr Giese, we learn that the quantity of benzoate of soda varies considerably in the urine of horses. In some specimens he found it in abundance, and easily precipitated by muriatic acid. In others there was little or none. He could detect no benzoic acid in the food of horses. Hence he considers it as formed within the animal, and he thinks that it appears only in cases of disease ‡.

The ass. II. The urine of the ASS was likewise examined by Mr Brande. It is transparent, but mucilaginous. It gives a green colour to syrup of violets, but no carbonate of lime is deposited from it on standing. It contains, according to Brande, urea, more phosphate of lime than the urine of the horse, carbonate of soda, sulphate of

* Ann. de Chim. lxvii. 276. † Ibid. 303.
‡ Phil. Mag. xvii. 151.

soda, muriate of soda, and probably muriate of potash. It contains no ammonia *. Chap. II.

III. The urine of the cow has a strong resemblance to that of the horse ; it has nearly the same odour, and the same mucilaginous consistence. It tinges syrup of violets green, and deposites a gelatinous matter. On standing, small crystals are formed on its surface. It contains, according to Rouelle, The cow.

1. Carbonate of potash
2. Sulphate of potash
3. Muriate of potash
4. Benzoic acid
5. Urea.

The urine of the cow has been recently examined by Mr Brande. He found it composed of the following constituents :

Water	65
Phosphate of lime	3
Muriate of potash, Muriate of ammonia	15
Sulphate of potash	6
Carbonate of potash, Carb. of ammonia	4
Urea	4
Loss	3
	100

He obtained from it likewise a quantity of benzoic acid, but conceives that this acid was formed during the process †.

IV. The urine of the CAMEL was also examined by Rouelle. Its odour resembles that of the urine of the The camel.

* *Ann. de Chim.* lxvii. 277. † Ibid. 268.

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cow ; its colour is that of beer ; it is not mucilaginous, and does not deposite carbonate of lime. It gives a green colour to syrup of violets, and effervesces with acids like the urine of the horse and cow. Rouelle obtained from it,

1. Carbonate of potash   3. Muriate of potash
2. Sulphate of potash   4. Urea

This urine has been recently examined by Mr Brande *. He obtained from it the following substances :

Water	75
Phosphate of lime Muriate of ammonia Sulphate of potash Urate of potash Carbonate of potash	6
Muriate of potash	8
Urea	6
Loss	5
	100

Chevreul subjected the urine of the camel to a rigid examination, on purpose to ascertain whether it really contained the phosphate of lime announced as a constituent of it by Mr Brande. He could detect none of it whatever, but separated from the urine of the camel the following substances :

Albumen
Carbonate of lime
Carbonate of magnesia

* *Ann. de Chim.* lxvii. 266.

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Silica
An atom of sulphate of lime
A trace of iron
Carbonate of ammonia
A little muriate of potash
A little sulphate of soda
Much sulphate of potash
A little carbonate of potash
Benzoic acid
Urea
A red oil, to which the urine owes its smell and colour.

The last substance, the oil, seems to have been taken by Brande for uric acid *.

The rabbit.

V. The urine of the RABBIT has been lately analysed by Vauquelin. When exposed to the air, it becomes milky, and deposites carbonate of lime. It gives a green colour to syrup of violets, and effervesces with acids. That chemist detected in it the following substances :

1. Carbonate of lime	6. Muriate of potash
2. Carbonate of magnesia	7. Urea
3. Carbonate of potash	8. Gelatine
4. Sulphate of potash	9. Sulphur.
5. Sulphate of lime	

The guinea pig.

VI. Vauquelin has also made some experiments on the urine of the GUINEA PIG ; from which it appears that it resembles the urine of the other quadrupeds. It deposites carbonate of lime, gives a green colour to syrup of violets, and contains carbonate and muriate of potash, but no phosphate nor uric acid †.

* *Ann. de Chim.* lxvii. 294.

† Fourcroy, x. 181.

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VII. From the late experiments of Fourcroy and Vauquelin, we learn that the urine of domestic fowls contains uric acid *.

The existence of that acid in the urine of fowls was called in question by Gehlen; but it has been fully confirmed by the late experiments of Chevreul †.

Thus it appears that the urine of the graminivorous quadrupeds agrees with the human in containing urea, but differs from it materially in being destitute of phosphoric acid, phosphates, and uric acid. Whether the urine of carnivorous quadrupeds contains these last substances has not been ascertained, but it is probable that it does.

SECT. XXIV.

OF FECES.

The excrementitious matter of animals, evacuated *per anum*, consists of all that part of the food which cannot be employed for the purposes of nutrition, considerably altered, at least in part, and mixed or united with various bodies employed during digestion to separate the

* *Jour. de Phys.* lix. 66.

† *Ann. de Chim.* lxvii. 3??.

useless parts of the food from the nutritious. An accurate examination of these matters has long been wished for by physiologists, as likely to throw much new light on the process of digestion. For if we knew accurately the substances which were taken into the body as food, and all the new substances which were formed by digestion; that is to say, the component parts of chyle and of excrement, and the variation which different kinds of food produce in the excrement, it would be a very considerable step towards ascertaining precisely the changes produced on food by digestion.

Some of the older chemists had turned their attention to the excrements of animals *; but no discovery of importance rewarded them for their disagreeable labour. Vauquelin has ascertained some curious facts respecting the excrementitious matter of fowls. In the summer of 1806, a laborious set of experiments on human feces was published by Berzelius, undertaken, as he informs us, chiefly with a view to elucidate the function of digestion †. About two years before, Thaer and Einhof had published a similar set of experiments on the excrements of cattle; made chiefly to discover, if possible, how they act so powerfully as manure ‡. I shall in this Section give a view of the results obtained by these different chemists.

Human feces.

I. The appearance of human feces requires no particular detail. Their colour is supposed to depend upon the bile mixed with the food in the alimentary canal. When too light, it is supposed to denote a de-

* Van Helmont's *Custos Errans*. Sect. vi.—*Opera Helmont*. p. 247.—*Newmann's Works*, p. 585. † Gehlen's *Jour*. vi. 509.
‡ Ibid. iii. 276.

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ficiency of bile; when too dark, there is supposed to be a redundancy of that secretion. The smell is fetid and peculiar, which after some time gradually changes into a sourish odour. The taste is sweetish bitter. The colour of vegetable blue infusions is not altered by fresh feces, indicating the absence of any uncombined acid or alkali *.

1. The consistency of human feces varies considerably in different circumstances; but at a medium, they may be stated to lose three-fourths of their weight when dried upon a water bath †.

Constituents.

2. They do not mix readily with water; but by sufficient agitation and maceration, they may be diffused through it. The liquid, in this state, being strained through a linen cloth, leaves a matter of a greyish brown colour, retaining a peculiar odour, which adheres long and obstinately to all those substances that come in contact with this residue. When dried, this substance exhibits the remains of vegetable matters used in food, and perhaps also of some animal matters. Its quantity amounts to about seven *per cent.* of the feces ‡.

3. The strained liquid deposited, on standing, a yellowish-green slimy matter, which was separated by the filter. It amounted when dry to 14 *per cent.* of the feces employed. From the numerous experiments of Berzelius upon this matter, it appears to be composed chiefly of three substances: 1. A fatty matter, separated by means of alcohol, which possesses many properties in common with the resin of bile, and which

* Gehlen's *Jour.* vi. 512. † Ibid. vi. p. 535.
‡ Ibid. p. 513.

Berzelius considers as that substance a little altered. 2. A peculiar yellow-coloured substance, dissolved by water after the fatty matter is removed. This substance Berzelius compares to gelatine; but it appears to be rather more closely allied to mucus, or, at least, to contain mucus as a constituent. It dissolves in water, but not in alcohol; tannin makes its solution muddy, but occasions no precipitate; acetate of lead occasions a copious white precipitate, but does not deprive the solution of its yellow colour. It soon runs to putrefaction, exhaling the odour of putrid urine. 3. A greenish grey residue, insoluble both in water and alcohol, and leaving, when incinerated, some silica and phosphate of potash *.

4. The liquid which passed through the filter was at first light yellow; but by exposure to the air it became brown, which gradually deepened in colour, till the solution grew at last muddy. When concentrated by evaporation, small transparent crystals made their appearance: which proved, on examination, to be crystals of ammonio-phosphate of magnesia. The solution, on examination, was found to contain the following substances: 1. Albumen, which was obtained by mixing the concentrated solution with alcohol. The precipitate consisted of a mixture of albumen and phosphoric salts. The albumen obtained from 100 parts of feces amounted only to 0·9 parts. 2. Bile. By this Berzelius understood a mixture of resin of bile and soda. The presence of this substance was inferred from the nature of the precipitate obtained by acids, and the salt

* Gehlen's *Jour.* vi. 526—534.

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of soda obtained by evaporating the residue. The quantity contained in 100 parts of feces was 0·9. 3. A peculiar substance, of a reddish brown colour, soluble both in water and alcohol. Acids give it an intense brown colour. A small quantity of tannin throws it down of a red colour and in a pulverulent form; a large quantity throws it down in greyish brown flakes. It is precipitated by muriate of tin, nitrate of silver, and acetate of lead. When heated it melts and emits the smell of ammonia. It leaves behind it, when burnt, traces of soda and of phosphoric salts. Berzelius supposes that this substance is formed from the resin of bile, by some change which it undergoes after the feces are exposed to the air. The quantity of it obtained from 100 parts of feces was 2·7 parts. 4. Various salts: These in all, from 100 parts of feces (including the ammonio-phosphate of magnesia), amounted to 1·2 parts. Their relative proportions were as follows:

Carbonate of soda	35
Muriate of soda	4
Sulphate of soda	2
Amm-phosphate of magnesia ..	2
Phosphate of lime	4

Such are the constituents of human feces, according to the experiments of Berzelius. The following Table exhibits the result of his analysis *.

* Gehlen's *Jour.* vi. 536.

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Water	73·3
Vegetable and animal remains	7·0
Bile	0·9
Albumen	0·9
Peculiar extractive matter	2·7
Salts	1·2
Slimy matter; consisting of resin of bile, peculiar animal matter, and insoluble residue	14·0
	100·0

Feces of cattle.

II. The excrementitious matter examined by Thaer and Einhof was that of cattle fed at the stall, chiefly on turnips. It had a yellowish green colour, a smell somewhat similar to that of musk, and but little taste. Its specific gravity was 1·045. It did not alter vegetable blues, and of course contained no uncombined acid or alkali.

1. Sulphuric acid, when mixed with this matter, developes the odour of acetic acid; but Thaer and Einhof have shown that this acid does not exist in the feces, but is formed by the action of the sulphuric acid. The pure alkalies, nitric and muriatic acids, produce little change on the feces of cattle, at least when not assisted by heat.

2. When 100 parts are dried on a steam bath, they leave $28\frac{1}{5}$ of solid matter.

3. When eight ounces, or 3840 grains, were diffused through water, they let fall a quantity of sand, weighing 45 grains.

4. The watery solution, being strained through a linen cloth, left 600 grains of a yellowish fibrous matter,

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which possessed the properties of the fibrous matter of plants *.

5. The liquid, on standing, deposited a slimy substance, which was separated by filtration. It weighed when dry 480 grains. To this matter the feces owe their peculiar colour and smell. It was insoluble in water and alcohol. When heated it smelled like ox bile. It burnt like vegetable matter. Alkalies scarcely affected it. Sulphuric acid developed the odour of acetic acid. Oxymuriatic acid rendered it yellow. Thaer and Einhof considered this substance as the remains of the vegetable matter employed as food by the cattle; but it is extremely probable that it might contain also a portion of the resin of bile, as Berzelius detected that substance in a similar matter from the human feces.

6. The filtered solution passed through colourless, but on exposure to the air became in a few minutes wine yellow and then brown. When evaporated to dryness it left a brownish matter, of a bitterish taste, and weighing 90 grains. It was soluble in water, insoluble in alcohol, and precipitated from water by that liquid. It was not precipitated by infusion of galls. The solution was found to contain some phosphoric salts. The 90 grains of residue, when heated, burnt like animal matter. They soon ran into putrefaction, exhaling ammonia †.

7. When evaporated to dryness and burnt, this excrementitious matter left behind it an ash, which was

* Gehlen, iii. 286. † Gehlen, iii. 287.

found (not reckoning the sand) to consist of the following salts and earths in the proportion stated *: Chap. II.

Lime	12
Phosphate of lime	12·5
Magnesia	2
Iron	5
Alumina with some manganese	14
Silica	52
Muriate and sulphate of potash	1·2

8. Thaer and Einhof made numerous experiments on the putrefaction of cow dung, both in close vessels and in the open air, from which it would appear that the process resembles closely the putrefaction of vegetable matter; the oxygen of the air being abundantly changed into carbonic acid †.

Excrements of fowls.

III. To Vauquelin we are indebted for an analysis of the fixed parts of the excrements of fowls, and a comparison of them with the fixed parts of the food; from which some very curious consequences may be deduced.

He found that a hen devoured in ten days 11111·843 grains troy of oats. These contained

126·509	grains phosphate of lime
219·548	silica
356·057	

During these ten days she laid four eggs; the shells of which contained 98·776 grains phosphate of lime, and 453·417 grains carbonate of lime. The excrements emitted during these ten days contained 175·529 grains phosphate of lime, 58·494 grains of carbonate of lime,

* Gehlen, iii. 321.   † Gehlen, iii. 295, 313.

had disappeared; but if so, it must be combined with a great quantity of some other substance *. Chap. II.

These consequences are too important to be admitted without a very rigorous examination. The experiment must be repeated frequently, and we must be absolutely certain that the hen has no access to any calcareous earth, and that she has not diminished in weight; because in that case some of the calcareous earth, of which part of her body is composed, may have been employed. This rigour is the more necessary, as it seems pretty evident, from experiments made long ago, that *some* birds at least cannot produce eggs unless they have access to calcareous earth. Dr Fordyce found, that if the canary bird was not supplied with lime at the time of her laying, she frequently died, from her eggs not coming forward properly †. He divided a number of these birds at the time of their laying eggs into two parties: to the one he gave a piece of old mortar, which the little animals swallowed greedily; they laid their eggs as usual, and all of them lived; whereas many of the other party, which were supplied with no lime, died ‡.

Vauquelin also ascertained, according to Fourcroy, that pigeons dung contains an acid of a peculiar nature, which increases when the matter is diluted with water; but gradually gives place to ammonia, which is at last exhaled in abundance §.

IV. The white matter voided by dogs who feed chiefly on bones, was formerly used in medicine under

* *Ann. de Chim.* xxix. 61.
† *On Digestion*, p. 25.
‡ Ibid. p. 26.
§ Fourcroy, x. 70.

Chap. II.

3. Biliary calculi
4. Urinary calculi
5. Gouty calculi

We shall take a view of each of these classes in order.

I. Ossifications.

All the concretions which make their appearance in the solids of the animal body may be comprehended under this title with propriety; because they have all a close resemblance to bone, being composed of similar constituents. The following are the most remarkable of these concretions.

1. Pineal concretions.

1. *Pineal concretions.*—It is well known to anatomists that small concretions like sand are often found lodged in that part of the brain called the *pineal gland*. It was suspected from analogy that they consisted chiefly of phosphate of lime; but Dr Wollaston was the first who examined them chemically, and proved the truth of this opinion. He dissolved some of the sand in nitric acid, and evaporated the solution; small crystalline needles made their appearance, indicating the presence of phosphate of lime *.

2. Salivary concretions.

2. *Salivary concretions.*—Small concretions occasionally make their appearance in the salivary glands, especially the parotid and sublingual. From the experi-

* See Dr Wollaston's important paper on Urinary and Gouty Concretions, *Phil. Trans.* 1797, p. 386.—I shall have occasion to refer to it very frequently in the subsequent part of this Section.

some cases they appear to contain no phosphate. Thus a pulmonary calculus examined by Mr Crumpton * was composed of

Carbonate of lime	82
Animal matter and water	18
	100

5. *Hepatic concretions.*—The liver also is sometimes full of similar bodies. The shape of the hepatic concretions, as far as my observations go, is more irregular, and I have seen them of greater size, than the pulmonary concretions. By my analysis, they are composed of phosphate of lime and a tough animal membranous matter. 5. Hepatic concretions.

6. *Concretions in the prostate.*—From the experiments of Dr Wollaston, we learn that the concretions which sometimes form in the prostate gland have likewise phosphate of lime for their basis. 6. Concretions in the prostate.

7. The extremities of the muscles and the larger blood vessels sometimes harden, and assume the appearance of bone. It is believed that this change is a real ossification, or that these bodies are converted into real bone. I do not know whether any such ossifications have been analysed. 7. Ossifications.

II. Intestinal Concretions.

Concretions of very considerable size are sometimes found lodged in the stomach and intestines; sel- History.

* *Phil. Mag.* xlii. 287.

not so easily separated as those of the preceding species *.

3. *Phosphate of ammonia-and-magnesia.*—This species is the most common of the intestinal concretions. Its colour is grey or brown, and it is composed of crystals diverging like rays from a centre. It has some resemblance to calcareous spar. It contains abundance of animal matter. This species occurs frequently in the intestines of herbivorous animals, as the horse, the elephant, &c.

4. *Biliary.*—This is a species of concretion found frequently in the intestines of oxen, and likewise in their gall-bladder, and employed by painters as an orange yellow pigment. Its colour is reddish brown. It is not composed of layers, but is merely a coagulated mass, and appears to be but little different from the resinous matter of bile. When heated it melts. It dissolves readily in alkalies. Alcohol dissolves it partially, and acquires a very bitter taste †.

5. *Resinous.*—To this species belong many of the oriental bezoards, formerly so celebrated, obtained from the intestines of animals with which we are unacquainted. They are fusible and combustible, composed of concentric layers, smooth, soft, and finely polished. Fourcroy and Vauquelin have distinguished two varieties: The first of a pale green colour, a slightly bitter taste, almost completely volatile; giving by heat a solid tenacious matter, soluble in alcohol, and separating in crystals as the solution cools. This matter consists partly of bile, partly of resin. The second variety has

* *Ann. de Mus. d'Hist.* iv. 332. † Ibid. 333.

they yielded the products of wood, and left a quantity of charcoal in the retort, which, when incinerated, gave traces of sulphate of soda, muriate of soda, lime, and silica. Thus it appears that they possessed all the properties of pure woody fibre. They must have been formed in the stomach of the animals, and not in the alimentary canal *.

III. Biliary Calculi.

History.

Hard bodies sometimes form in the gall-bladder, or in the duct through which the bile passes into the intestinal canal, and stop up the passage altogether. These concretions have got the name of *biliary calculi* or *gall-stones.* They naturally drew the attention of physicians, because it was soon ascertained that they occasioned the disease called *jaundice.* Accordingly they were examined and described by different chemists; and the facts ascertained before 1764 were collected by Haller in the sixth volume of his Physiology. Since that period, a treatise has been published on them by Vicq d'Azyr; and several new facts have been discovered by Poulletier de la Sale, Fourcroy, Gren, and Saunders. Thenard has lately subjected them to examination †.

Divisible into four classes.

Such of the biliary calculi as have been hitherto examined with attention may be arranged under four classes.

1. The first kind comprehends those which have a

* *Mem. d'Arcueil*, ii. 448.

† Ibid. i. 59.

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white colour, and a crystallized, shining, lame
structure. They consist of adipocire.

2. The second species are polygonal, of a light
ish brown colour. Externally they have a co
composed of thin concentric layers, within a mat
ther crystallized or having the appearance of co
ted honey. They are composed chiefly of adipo
but contain a small portion of brown matter, consi
as yellow matter of bile a little altered.

3. The third kind are of a brown colour, an
supposed to be composed of altered yellow matt
bile.

4. The fourth comprehends those gall-stones w
do not flame, but gradually waste away at a red h

Let us take a view of each of these classes of b
calculi.

1st Species resembles spermaceti.

1. The first species of biliary calculi was po
out for the first time by Haller in a dissertation
lished in 1749. Walther afterwards added se
new facts; and at last it was accurately describe
Vicq d'Azyr. It is almost always of an oval s
sometimes as large as a pigeon's egg, but comm
about the size of a sparrow's; and for the most
only one calculus (when of this species) is found i
gall-bladder at a time. It has a white colour;
when broken, presents crystalline plates or striæ,
liant and white like mica, and having a soft greasy
Sometimes its colour is yellow or greenish; and it
constantly a nucleus of inspissated bile *. Its spe

* Fourcroy, *Ann. de Chim.* iii. 249.

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gravity is inferior to that of water: Gren found the specific gravity of one 0·803 *.

When exposed to a heat considerably greater than that of boiling water, this crystallized calculus softens and melts, and crystallizes again when the temperature is lowered †. It is altogether insoluble in water; but hot alcohol dissolves it with facility. Alcohol, of the temperature of 167°, dissolves $\frac{1}{10}$ of its weight of this substance; but alcohol, at the temperature of 60°, scarcely dissolves any of it ‡. As the alcohol cools, the matter is deposited in brilliant plates resembling talc or boracic acid §. It is soluble in oil of turpentine ‖. When melted it has the appearance of oil, and exhales the odour of melted wax: when suddenly heated it evaporates altogether in a thick smoke. It is soluble in pure alkalies, and the solution has all the properties of a soap. Nitric acid also dissolves it; but it is precipitated altered by water ¶. Indeed the greatest part separates as the liquid cools, and swims on the surface like drops of oil, and seems by the action of the acid to be brought nearly to the state of a resin **. Fourcroy, who first examined this peculiar matter of biliary calculi, has given it the name of *adipocire*, from its resemblance both to fat and to wax.

2d Species nearly similar.

2. The second kind of biliary calculi is of a polygonal shape, and a number of them almost always exist in the gall-bladder together. To this, probably, they owe their peculiar form. Most commonly they have

* *Ann. de Chim.* v. 186. † Ibid. ii. 123.
‡ Ibid. ii. 180. [illegible] 6. ‖ Gren, Ibid. v. 187.
¶ Fourcroy, Ibid. iii. 24[illegible] Nicholson's *Jour.* iv. 138.

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three blunt angles, and have some resemblance to two low tetrahedons, applied base to base, with their edges and angles rounded off. They vary considerably in their specific gravity. A specimen seemingly belonging to this species, examined by Dr Bostock, was of the specific gravity 0·900 *. The mean specific gravity of six which I analysed was 1·061, and they all sunk in water. Their outer surface is smooth, and has a soft feel. When broken they exhibit a thin outer crust, composed of concentric layers, alternately crystallized in small rays inclining towards the centre. The nucleus, in all the specimens which I have examined, had the appearance of granulated honey.

These calculi, in their composition, differ but little from the last species, since they consist almost entirely of adipocire. In six gall-stones which I analysed, this matter amounted to at least $\frac{18}{20}$ths of the whole. The residue was a reddish brown substance, insoluble in alcohol. Nitric acid dissolved it readily, and formed a pink-coloured liquid, from which ammonia threw down no precipitate. Pure potash ley dissolved most of it readily when assisted by heat. From the solution, muriatic acid threw down a dark green matter, which had a bitter taste, dissolved in alcohol, melted when heated, and exhibited most of the properties of the resin of bile. The residue, insoluble in potash, was in grey flakes, and resembled albumen in such of its properties as could be traced. But as it never exceeded $\frac{1}{9}$th of a grain, it was not possible to ascertain its nature with precision.

* Bostock, Nicholson's *Jour.* iv. 236.

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3d, Of altered yellow matter.

3. I have never had an opportunity of seeing any gall-stones from the human species belonging to the third kind, or composed entirely of altered yellow matter. But in the gall-stones examined by Thenard several were of this kind.

4. Concerning the fourth species of gall stone very little is known with accuracy. Dr Saunders tells us that he has met with some gall-stones insoluble both in alcohol and oil of turpentine; some of which do not flame, but become red, and consume to an ash like a charcoal *. Haller quotes several examples of similar calculi †. Probably they do not differ from the third kind.

5. The gall stones of oxen are always of a yellow colour, and consist of the yellow matter of bile mixed with minute traces of bile which may be separated by water. They are tasteless, when thus washed, and insoluble in water and alcohol. They are used by painters, though their colour is not permanent, but soon changes to a brown ‡.

IV. Urinary Calculi.

It is well known that concretions not unfrequently form in the bladder, or the other urinary organs, and occasion one of the most dismal diseases to which the human species is liable.

History.

These concretions were distinguished by the name of *calculi*, from a supposition that they are of a stony na-

* On the *Liver*, p. 112. † *Physiol.* vi. 567.

‡ Thenard, *Mem. d'Arcueil*, i. 59.

Drs Whytt and Alston pointed out alkalies as solvents of calculi. It was an attempt to discover a more perfect solvent that induced Dr Black to make those experiments which terminated in the discovery of the nature of the alkaline carbonates.

Such was the state of the chemical analysis of calculus, when in 1776, Scheele published a dissertation on the subject in the Stockholm Transactions; which was succeeded by some remarks of Mr Bergman. These illustrious chemists completely removed the uncertainty which had hitherto hung over the subject, and ascertained the nature of the calculi which they examined.

Since that time considerable additional light has been thrown upon the nature of these concretions by the labours of Austin, Walther, Brugnatelli, Pearson, &c. But the most important additions to our knowledge of calculi were made by Dr Wollaston. That ingenious chemist distinguished them into species, and ascertained the composition of each, pointing out several new constituents which had not been suspected before *. The dissertation on calculi by Fourcroy and Vauquelin is no less important. Many of their results indeed had been anticipated by Wollaston: But they analysed about 500 calculi with precision; a number sufficient to enable them to make a more exact arrangement of them than could be obtained, till the frequency of the occurrence of every ingredient was known. They detected also some substances in calculi which had not been observed in them before. A valuable dissertation on the subject has lately been published by Mr Brande. He

* *Phil. Trans.* 1797.

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examined 150 calculi in the
rectified some mistakes of
several new facts *.

Descrip-tion.

. Urinary calculi are usuall
sometimes they are polygc
of mulberries; and in tha
by the epithet *mulberry*.
times they are very small,
goose-egg, or even larger.
is a deep brown resemblin
cases they are white, and
of a dark grey, and hard.
often intermixed, and occu
sity. Their surface in
marble; in others, rough a
are covered with semitrans
cific gravity varies from 1

Component parts.

The substances hitherto
are the following:

1. Uric acid
2. Phosphat
3. Phosphat
4. Oxalate o
5. Muriate c
6. Magnesia
7. Phosphat
8. Silica
9. Urea

* *Phil. Trans.* 1808.

‡ Brugnatelli found also phospha
culi.—See *Ann. de Chim.* xxxii. 183.

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10. Cistic oxide

11. Mucus

1. Uric acid.

1. Uric acid was first discovered in calculi by Scheele. 'he greater number of these concretions hitherto ana-ysed consisted of it. All those analysed by Scheele 'ere composed of it entirely. Of 300 calculi analysed y Dr Pearson, scarcely one was found which did not ontain a considerable quantity of it, and the greater umber manifestly were formed chiefly of it. Fourcroy ıd Vauquelin found it also in the greater number of ıe 500 calculi which they analysed. Of 150 exami-ed by Brande only 16 were composed entirely of this cid; but almost the whole of them contained this acid.

The presence of this acid may be easily ascertained y the following properties: The calculi formed of it re brown, polished, and resemble wood. A solution f potash or soda dissolves it readily, and it is precipi-ated by the weakest acids. The precipitate is soluble ı nitric acid; the solution is of a pink colour, and inges the skin red.

2. Phosphate of lime.

2. Phosphate of lime was observed in calculi by Berg-nan; afterwards it was found in abundance by Pear-on, and more lately by Fourcroy and Vauquelin. Dr Vollaston was the first who observed calculi composed f it entirely. The calculi which he examined were rown, and so smooth externally as to appear polished. They were composed of laminæ easily separable into oncentric crusts. In the calculi observed by Fourcroy ınd Vauquelin, the phosphate of lime was white, with-out lustre, friable, stained the hands, paper, and cloth. It had very much the appearance of chalk, broke under he forceps, was insipid and insoluble in water. It is oluble in nitric, muriatic, and acetic acids, and is

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of their characters was known till they attracted the attention of that chemist. In all the calculi which he examined, the oxalate was mixed with phosphate of lime, and usually also with uric acid; but Fourcroy and Vauquelin found several in which it was united only to animal matter. It commonly forms a very hard calculus, of a dark green colour, difficult to saw asunder, admitting a polish like ivory, exhaling, when sawed, an odour like that of semen. Insoluble and indecomposable by alkalies; soluble in very diluted nitric acid, but slowly and with difficulty. It may be decomposed by the carbonates of potash and soda. When burnt, it leaves behind a quantity of pure lime, amounting to one-third of its weight, which may be easily recognised by its properties *.

5. Muriate of ammonia was first detected in calculi by Brande. Fourcroy and Vauquelin had announced the existence of urate of ammonia in calculi. They founded their opinion chiefly on the easy solubility of the supposed urate in alkaline leys, and the smell of ammonia given out during the solution. Brande found that if such calculi were treated with water, a portion was dissolved, and the residue consisted of pure uric acid. The matter dissolved was partly urea and partly muriate of ammonia. To the first of these bodies he ascribed the easy solubility of the calculus, and to the second the smell of ammonia which it gave out during its solution. From his experiments it does not appear that any such salt as urate of ammonia is present in calculi †.

5. Muriate of ammonia.

* Fourcroy, *Ann. de Chim.* xxxii. 220. † *Phil. Mag.* xxxii. 171.

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Phosphate of lime	17·33
Uric acid	75·34
Animal matter.........	6·33
Silica	1·00
	100·00 *

Silica was found also in an excessive proportion in the calculus analysed by Alemani, the result of which has been stated above.

9. Urea. 9. Urea was suspected to exist in calculi by Fourcroy and Vauquelin, but was first detected by Mr Brande. He obtained it by digesting the calculi supposed to contain it in water or alcohol, and evaporating the solution. The proportion of it seems sometimes to be great. In one instance Mr Brande found 36 *per cent.* of animal matter, the greatest part of which no doubt was urea †.

10. Cistic oxide. 10. The substance called cistic oxide was discovered, and its nature ascertained, by Dr Wollaston. A small calculus, passed from the bladder of a man, was entirely composed of it. It was white, dense, brittle, and had pretty much the appearance of magnesian lime-stone. The characters of this new and peculiar animal substance, as ascertained by Dr Wollaston, are the following: 1. It dissolves and combines equally with acids and alkalies, and crystallizes with both. 2. It is precipitated from nitric acid by alcohol. 3. It does not become red when treated with nitric acid. 4. It produces no change on vegetable blues. 5. It is insoluble in water, alcohol, and ether. 6. When distilled it

* Gehlen's *Jour.* Second Series. ii. 265. † *Phil. Mag.* xxxii. 171.

GENUS II. *Calculi composed of two ingredients.*

Sp. 1. Uric acid and the phosphates in layers.

Sp. 2. Ditto mixed together.

Sp. 3. Urate of ammonia and the phosphates in layers.

Sp. 4. Ditto mixed together.

Sp. 5. The phosphates mixed or in layers.

Sp. 6. Oxalate of lime and uric acid in layers.

Sp. 7. Oxalate of lime and the phosphates in layers.

GENUS III. *Calculi containing more than three ingredients.*

Sp. 1. Uric acid, the phosphates, and oxalate of lime.

Sp. 2. Uric acid, urate of ammonia, the phosphates, silica.

Let us take a view of each of these species.

Description of the species.

Sp. 1. *Uric acid.* Colour that of wood, various shades of yellow or red. Texture laminar and radiated, compact and fine. Specific gravity from 1·5 to 1·786; sometimes so low as 1·276. Surface usually smooth and polished. Completely soluble in fixed alkaline leys, without emitting any odour of ammonia. This species is the most common. One fourth of the 600 calculi examined by Fourcroy and Vauquelin belonged to it.

Sp. 2. *Urate of ammonia.* Colour brownish white. Texture laminar, laminæ easily separated from each other. Specific gravity from 1·225 to 1·720. Surface often crystallized. Soluble in hot water, especially when reduced to powder. Soluble in fixed alkalies,

but its nucleus, instead of uric acid, is composed of urate of ammonia. It is not very common, and the calculi belonging to it are smaller than those of the fourth species.

Sp. 7. *Urate of ammonia and the phosphates mixed.* This species resembles the fifth, but may be distinguished by a colour less yellow, and by the ammonia emitted when the calculi are treated with potash. The calculi belonging to it are small and rather uncommon.

Sp. 8. *The two phosphates mixed or in layers.* Colour white like chalk. Texture laminar; friable, easily separated, and staining the surface of other bodies like chalk. Often mixed with thin layers of phosphate of magnesia-and-ammonia, sparry, and semitransparent. Specific gravity from 1·138 to 1·471. Soluble in acids, insoluble in alkalies. About $\frac{1}{15}$th of the calculi examined by Fourcroy and Vauquelin belonged to this species.

Sp. 9. *Oxalate of lime and uric acid in layers.* The calculi belonging to this species have a nucleus of oxalate of lime covered with a layer, more or less thick, of uric acid; or they consist of a small calculus of the third species covered with a layer belonging to the first species. They are easily distinguished when sawn in two. About $\frac{1}{30}$th of the 600 calculi analysed by Fourcroy and Vauquelin belonged to this species.

Sp. 10. *Oxalate of lime and the phosphates in layers.* The calculi belonging to this species have a nucleus of oxalate of lime covered with a coat of the phosphates. Externally, therefore, they are the same with the fourth and eighth species; while the internal nucleus belongs to the third species. They are easily distinguished therefore when sawn in two. The calculi of this spe-

3. *Mulberry calculi.* Composed of oxalate of lime or of oxalate and phosphate of lime. In the state of powder they are slowly dissolved by muriatic acid. The residuum is uric acid.

4. *Bone earth calculi.* These, as the name implies, are composed chiefly of phosphate of lime. They are soluble in muriatic acid.

From the observations and experiments of Mr Brande, it appears that the calculi formed in the kidneys, almost always consist of uric acid and animal matter. Sometimes, but very rarely, they consist of oxalate of lime; and when calculi remain in the kidney a considerable time after they have been formed, their external coat consists sometimes of the triple phosphate of magnesia and phosphate of lime *.

Of 150 calculi found in the bladder, and analysed by Mr Brande, the following was the composition:

16	Composed of uric acid
45	.... uric acid, with a small relative proportion of the phosphates
66	.... the phosphates with a small proportion of uric acid
12	.... the phosphates entirely
5	.... uric acid with the phosphates and nuclei of oxalate of lime
6	.... chiefly oxalate of lime.
150†	

From the preceding account of the different urinary calculi, it appears that most of their component parts

* *Phil. Mag.* xxxii. 167. † Ibid. xxxii. 171.

therefore pass over the numerous lithonthriptics* which have been recommended in all ages, and satisfy myself with giving an account of the experiments made by Fourcroy and Vauquelin to dissolve stones by injections through the urethra, made after their analysis of the urinary calculi.

The component parts of urinary calculi, as far as solvents are concerned, may be reduced under three heads;

Solvents.

1. Uric acid and urate of ammonia
2. The phosphates
3. Oxalate of lime.

1. A solution of pure potash and soda, so weak that it may be kept in the mouth, and even swallowed without pain, soon dissolves calculi composed of uric acid, or urate of ammonia, provided they be kept plunged in it.

2. The phosphates are very quickly dissolved by nitric or muriatic acid, so weak that it may be swallowed without inconvenience, and possessed of no greater acridness than urine itself.

3. Oxalate of lime is much more difficult of solution than the preceding substances. Calculi composed of it are slowly dissolved by nitric acid, or by carbonate of potash or soda, weak enough not to irritate the bladder: but the action of these substances is slow, and scarcely complete.

How applied.

These solvents injected into the bladder repeatedly, and retained in it as long as the patient can bear their action without inconvenience, ought to act upon the

* There is no room to believe that any of these medicines hitherto proposed, whether alkalies or acids, have any effect as solvents of calculi.

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stone, and gradually dissolve it. The difficulty, however, is to determine the composition of the calculus to be acted upon, in order to know which of the solvents to employ. But as no method of deciding this point with certainty is at present known, we must try some one of the solvents for once or twice, and examine it after it has been thrown out of the bladder. Let us begin, for instance, with injecting a weak solution of potash; and after it has remained in the bladder half an hour, or longer if the patient can bear it, let the liquid, as soon as passed, be filtered and mixed with a little muriatic acid; if any uric acid has been dissolved, a white solution will make its appearance. This precipitate is a proof that the calculus is composed of uric acid. If it does not appear, after persevering in the alkaline solution for some days, then there is reason to expect the presence of the phosphates; of course a weak muriatic acid solution should be injected. After this solution is emitted, let it be mixed with ammonia, and the phosphate of lime will precipitate, if the calculus be composed of it. If neither of these solutions take up any thing, and if the symptoms are not alleviated, we must have recourse to the action of nitric acid, on the supposition that the calculus is composed of oxalate of lime. These different solutions must be persisted in, and varied occasionally as they lose their efficacy, in order to dissolve the different coats of the calculus. Such are the methods pointed out by Fourcroy and Vauquelin. It is scarcely necessary to observe, that the bladder should be evacuated of urine previous to the injections, and that the injections should be previously heated to the temperature of the body.

Calculi of inferior animals.

The calculi found in the bladder of the inferior animals have been examined by different chemists, especially by Fourcroy and Vauquelin, and by Dr Pearson and Mr Brande. As far as experiment has hitherto gone, they consist chiefly of the three following species.

1. *Carbonate of lime.* These calculi have a white colour, are opaque, and are easily recognized by the action of acids. They occur most frequently in the bladder of the graminivorous animals, and seem to have been first detected by Fourcroy and Vauquelin. The lime is cemented by an animal matter. Calculi belonging to this species have been found in the bladder of the horse *, the sow †, the rabbit *, the ox ‡.

2. *Earthy phosphate.* These calculi belong chiefly to the carnivorous animals, and seem first to have been examined by Dr Pearson. They consist sometimes of phosphate of lime and animal matter, sometimes of a mixture of phosphate of lime and phosphate of ammonia-and-magnesia and animal matter. They have been found in the bladder of the dog §, the hog ‖, the rat ¶, and the cat ¶: And a calculus from a horse, examined by Dr Pearson, was obviously composed of the two phosphates.

3. *Oxalate of lime.* Calculi composed of this substance have been recently detected by Fourcroy and Vauquelin from the bladder of the dog and the rat **.

* Pearson. † Brugnatelli and Fourcroy. ‡ Fourcroy.
§ Pearson. ‖ Bartholdi. ¶ Fourcroy and Vauquelin.
** *Ann. de Mus. d'Hist. Nat.* iv. 338.

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The following table exhibits a view of the constituents of the calculi of different animals analysed by Mr Brande :

	Horse *.			Sheep.	Dog.		Hog.	Rabbit.
Phosphate of lime	76	45	60	72	64	80		[illegible]
Carbonate of lime	22	10	40	20		20	90	[illegible]
Phosph. of mag. and ammonia		28			30			
Animal matter		15		8	6		10	[illegible]
Loss	2	2						
	100	100	100	100	100	100	100	100

Several calculi from the bladder of the ox, likewise examined by Mr Brande, were composed of carbonate of lime and animal matter †.

Thus it appears that the calculi of carnivorous animals resemble the human in their composition, excepting that uric acid has never been detected in them.

V. Gouty Concretions.

It is well known that concretions occasionally make their appearance in joints long subject to gout. These concretions, from their colour and softness, have received the name of *chalk stones*. They are usually small,

Chalk stones.

* The first calculus in the table was from the kidney, all the rest were from the bladder.

† *Phil. Mag.* xxxii. 175.

though they have been observed of the size of an egg *. It had long been the opinion of physicians that these concretions were similar to the urinary calculi. Of course, after the discovery of uric acid by Scheele, it was usual to consider the gouty chalk stones as collections of that acid. They were subjected to a chemical analysis by Dr Wollaston in 1797, who found them composed of uric acid and soda.

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Consist of urate of soda.

Gouty concretions are soft and friable. Cold water has little effect upon them; but boiling water dissolves a small portion. If an acid be added to this solution, small crystals of uric acid are deposited on the sides of the vessel.

These concretions are completely soluble in potash when the action of the alkaline solution is assisted by heat.

When treated with diluted sulphuric or with muriatic acid, the soda is separated; but the uric acid remains, and may be separated by filtration. The liquid, when evaporated, yields crystals of sulphate or muriate of soda, according to the acid employed. The residuum possesses all the characters of uric acid. When distilled it yields ammonia, prussic acid, and the acid sublimate of Scheele. When dissolved in a little nitric acid, it tinges the skin of a rose colour, and when evaporated leaves a rose-coloured deliquescent residuum. It is soluble in potash, and may be precipitated by any acid, and by ammonia; first in the state of a jelly, and then breaking down into a white powder.

* Severinus.

given. It will be worth while, however, to state the observations that have been made.

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I. Pus.

The liquid called *pus* is secreted from the surface of an inflamed part, and usually moderates and terminates the inflammation. It assumes different appearances according to the state of the sore. When it indicates a healing sore, it is called *healthy* or *good-conditioned* pus. This liquid possesses the following properties:

Properties of healthy pus.

It is of a yellowish-white colour, and of the consistence of cream. Its taste is insipid, and it has no smell when cold. Before the microscope it exhibits the appearance of white globules swimming in a transparent fluid *.

It produces no change on vegetable blues †. When exposed to a moderate heat it gradually dries, and assumes the appearance of horn. When exposed to destructive distillation, Bergman obtained first about one-fourth of the pus in the state of insipid water. On increasing the fire, a liquid came over, containing abundance of ammonia, and accompanied by gaseous bodies, which were not examined. Some concrete carbonate of ammonia sublimed, accompanied by empyreumatic oil. A light brilliant coal remained of difficult incineration. The ashes gave traces of iron ‡.

When pus is left exposed to the air, it gradually becomes acid, according to Hildebrant; and Haller af-

* Home on *Ulcers*.

† Cruickshanks.

‡ Gren's *Handbuch*, ii. 426.

Such are the properties of healthy pus hitherto observed by chemists. They indicate a considerable analogy with albumen. Various observations have been made to enable physicians to distinguish pus from the mucus of the internal cavities, especially of the lungs. In cases of copious expectoration, it is sometimes of consequence to know whether the matter thrown out of the lungs is pus or mucus. Mr Charles Darwin made a set of experiments on the subject, and pointed out three criteria which distinguished pus. 1. Sulphuric acid dissolves it. When the solution is diluted the pus precipitates; but mucus treated in the same manner swims. But this distinction depends upon the quantity of water added, and is therefore ambiguous. 2. Pus is diffusible through diluted sulphuric acid, through water, and through brine; but mucus is not. 3. Alkaline leys dissolve pus; water precipitates pus thus dissolved, but not mucus. How far these two last distinctions can be trusted, is rather doubtful. Grasmeyer has proposed the following method, which he considers as complete. Triturate the substance to be tried with an equal quantity of warm water; then add to it an equal portion of a saturated solution of carbonate of potash, and set the mixture aside. If it contains pus, a transparent jelly subsides in a few hours; but this does not happen if only mucus be present *.

2. When the ulcer is ill-conditioned, the pus secreted in it possesses different properties. It has usually a fetid smell, is much thinner, and to a certain degree acrid.

* Gren's *Handbuch*, ii. 433.

Crawford found that the odour of this matter was completely destroyed by oxymuriatic acid; and therefore recommends it as a proper substance for washing cancerous ulcers.

4. Besides the species mentioned above, there are many others which we know from their effects to be peculiar, though we cannot find any chemical distinctions between them sufficiently well marked. But that they are specifically different cannot be doubted, if we consider that every one of them produces a disease peculiar to itself. The matter of small pox, of venereal ulcers, of cow-pox, &c. may be mentioned as instances.

II. Liquor of Dropsy.

The liquor which fills the cavities of the body in dropsy has a yellowish green colour, and is sometimes turbid, sometimes nearly transparent. A few experiments on a colourless liquor extracted from a dropsical patient have been published by Wurzer: from which it appears to have contained albumen, mucus, sulphureted hyrogen, phosphate of lime, and muriate of soda, and soda *. To Dr Bostock we are indebted for an examination of the colourless liquid obtained by puncturing a tumor in the spine, formed in the disease called *spina bifida*. It was slightly opaque, and did not alter vegetable blues; heat increased its opacity, but did not coagulate it. Its constituents were found to be as follows:

* Gehlen's *Jour.* v. 663.

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Water	97·8	
Muriate of soda	1·0	
Albumen	0·5	
Mucus	0·5	proportions conjectural
Gelatine	0·2	proportions conjectural
Lime, a trace		
	100·0*	

III. Liquor of Blisters.

The liquid which makes its appearance when the epidermis is raised into blisters is perfectly transparent and liquid. When the blisters are artificial, it is usually yellow, and has the odour of the blistering plaster. From the experiments of Margueron, we learn that it is composed of the same constituents as the serum of the blood. From 200 parts of this liquid he obtained,

Constituents.

36 albumen
4 muriate of soda
2 carbonate of soda
2 phosphate of lime
156 water

200†

Thus I have given an account of all those secretions which have been attentively examined by chemists.

* Nicholson's *Jour.* xiv. 145. † *Ann. de Chim.* xiv. 2[illegible].

The remainder have been hitherto neglected; partly owing to the difficulty of procuring them, and partly on account of the multiplicity of other objects which occupied the attention of chemical philosophers. It remains for us now to examine by what processes these different secretions are formed, how the constant waste of living bodies is repaired, and how the organs themselves are nourished and preserved. This shall form the subject of the following Chapter.

CHAP. III.

OF THE FUNCTIONS OF ANIMALS.

The intention of the two last Chapters was to exhibit a view of the different substances which enter into the composition of animals, as far as the present limited state of our knowledge puts it in our power. But were our inquiries concerning animals confined to the mere ingredients of which their bodies are composed, even supposing the analysis as complete as possible, our knowledge of the nature and properties of animals would be imperfect indeed.

How are these substances arranged? How are they produced? What purposes do they serve? What are the distinguishing properties of animals, and the laws by which they are regulated?

Animals resemble vegetables.

Animals resemble vegetables in the complexness of their structure. Like them, they are machines nicely adapted for particular purposes, constituting one whole, and continually performing an infinite number of the most delicate processes. But neither an account of the structure of animals, nor of the properties which distinguish them from other beings, will be expected here: These topics belong entirely to the anatomist and physiologist. I mean in the present Chapter to take a view

of those processes only that are concerned in the *production* of animal substances, which alone properly belong to Chemistry. The other functions are regulated by laws of a very different nature, which have no resemblance or analogy to the laws of Chemistry or Mechanics.

SECT. I.

OF DIGESTION.

Food necessary.

EVERY body knows that animals require food, and that they die sooner or later if food be withheld from them. There is indeed a very great difference in the quantity of food which animals require, and in the time which they can pass without it. In general, those animals which are most active require most, and those which are most indolent require least food. The cause of this is pretty obvious; the bodies of animals do not remain stationary, they are constantly wasting; and the waste is proportional to the activity of the animal. Hence the body must receive, from time to time, new supplies, in place of what has been carried off. The use of food answers this purpose.

Its nature.

2. We are much better acquainted with the food of animals than of vegetables. It consists of almost all the animal and vegetable substances which have been treated of in this and the preceding Book: for there are but very few of them which some animal or other does not use as food. Man uses as food chiefly the muscles of animals, the seed of certain grasses, and a variety of

Book V. vegetable fruits. Almost
particular substances on w
Some of them feed on ani
Man has a greater range ;
number of substances. T
would be useless ; as we a
accuracy what it is whicl
nourishing than another.

Many substances do not
and not a few, instead of n
last are called *poisons*. Son
decomposing the animal b
not so well understood.

Converted into chyme in the stomach.

3. The food is introd
mouth, and almost all a
pulpy consistence. In m
this is done in the mouth
liva with which it is there
mals grind their food in a
food has been thus groun
stomach, where it is sub
stomach is a strong soft b
ferent animals : in man it
bag of a *bag pipe*. In th
into a soft pap, which ha
when first introduced. Th

4. Since chyme posses
dent that the food has unc
stomach, and that the ingr
posed have entered into t
what manner have these c

At first they were ascril
of the stomach. The fo

ther triturated in that organ: and being long agitated backwards aad forwards in it, was at last reduced to a pulp. But this opinion, upon examination, was found not to be true. The experiments of Stevens, Reaumur, and Spallanzani, demonstrated that the formation of chyme is not owing to trituration; for on inclosing different kinds of food in metallic tubes and balls full of holes, in such a manner as to screen them from the mechanical action of the stomach, they found that these substances, after having remained a sufficient time in the stomach, were converted into chyme, just as if they had not been inclosed in such tubes. Indeed the opinion was untenable, even independent of these decisive experiments, the moment it was perceived that chyme differed entirely from the food which had been taken: that is to say, that if the same food were triturated mechanically out of the body, and reduced to pap of precisely the same consistence with chyme, it would not possess the same properties with chyme; for whenever this fact was known, it could not but be evident that the food had undergone changes in its composition.

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This change ascribed to the mechanical action of the stomach.

The change of food into chyme therefore was ascribed by many to *fermentation*. This opinion is indeed very ancient, and it has had many zealous supporters among the moderns. When the word *fermentation* was applied to the change produced on the food in the stomach, the nature of the process called *fermentation* was altogether unknown. The appearances, indeed, which take place during that process had been described, and the progress and the result of it were known: but no attempt had been made to explain the cause of fermentation, or to trace the changes which take place during its continuance. All that could be meant, then, by

Ascribed to fermentation,

Book V. saying that the conversion
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soon digested in the stomach of the dog. Further, if conversion of food into chyme were owing to fer- ntation, it ought to go on equally well in the stomach l œsophagus. Now, it was observed long ago by y and Boyle, that when voracious fish had swallowed imals too large to be contained in the stomach, that t only which was in the stomach was converted into yme, while what was in the œsophagus remained en- e; and this has been fully confirmed by subsequent servations.

Still farther, if the conversion were owing to fermen- ion, it ought always to take place equally well, pro- led the temperature be the same, whether the sto- ich be in a healthy state or not. But it is well known it this is not the case. The formation of chyme de- nds very much on the state of the stomach. When it organ is diseased, digestion is constantly ill perform- . In these cases, indeed, fermentation sometimes ap- ars, and produces flatulence, acid eructations, &c. iich are the well-known symptoms of indigestion. iese facts, which have been long known, are incom- tible with the supposition, that the formation of yme is owing to fermentation. Accordingly that opi- on has been for some time abandoned, by all those at ist who have taken the trouble to examine the subject.

Owing to the action of the gastric juice.

The formation of chyme, then, is owing to the sto- ach; and it has been concluded, from the experiments Stevens, Reaumur, Spallanzani, Scopoli, Brugna- li, Carimini, &c. that its formation is brought about the action of a particular liquid secreted by the sto- ach, and for that reason called *gastric juice*.

That it is owing to the action of a liquid is evident; ecause, if pieces of food be inclosed in close tubes,

The gastric juice does not continue always of the same nature, even in the same animal; it changes gradually according to circumstances. Graminivorous animals may be brought to live on animal food; and after they have been accustomed to this for some time, their stomachs become incapable of digesting vegetables. On the other hand, those animals which naturally digest nothing but animal food may be brought to digest vegetables. Chap. III.

5. What is the nature of the gastric juice which possesses these singular properties? It is evidently different in different animals; but it is a very difficult task, if not an impossible one, to obtain it in a state of purity. Various attempts have indeed been made by very ingenious philosophers to procure it; but their analysis of it is sufficient to show us that they have never obtained it in a state of purity.

Methods of procuring it.

The methods which have been used to procure gastric juice are, *first*, to kill the animal whose gastric juice is to be examined after it has fasted for some time. By this method Spallanzani collected 37 spoonfuls from the two first stomachs of a sheep. It was of a green colour, undoubtedly owing to the grass which the animal had eaten. He found also half a spoonful in the stomach of some young crows which he killed before they had left their nest.

Small tubes of metal pierced with holes, and containing a dry sponge, have been swallowed by animals; and when vomited up, the liquid imbibed by the sponge is squeezed out. By this method, Spallanzani collected 481 grains of gastric juice from the stomachs of five crows.

A *third* method consists in exciting vomiting in the

could excite vomiting whenever ... swallowing air, has employed tl... gastric juice.

Spallanzani has observed that ... morning a quantity of liquid, whi... tric juice; and he has availed hir... it in considerable quantities.

It is almost unnecessary to r... these different methods are, and ... sion drawn from the examinatio... deviate from the truth. It is imp... juice obtained by any one of th... pure; because in the stomach i... mixed with large quantities of sal... &c. It may be questioned, inde... tric juice at all can be obtained b... as the intention of the gastric ju... food into chyme, in all probabili... or at least thrown into the stoma... sent.

Attempts to analyse it.

We need not be surprised, the... accounts concerning its nature, giv... sophers who have attempted to ex... late not so much to the gastric ju...

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According to Brugnatelli, the gastric juice of carnivorous animals, as hawks, kites, &c. has an acid and resinous odour, is very bitter, and not at all watery; and is composed of an uncombined acid, a resin, an animal substance, and a small quantity of muriate of soda *. The gastric juice of herbivorous animals, on the contrary, as goats, sheep, &c. is very watery, a little muddy, has a bitter saltish taste, and contains ammonia, an animal extract, and a pretty large quantity of muriate of soda †. Mr Carminati found the same ingredients; but he supposes that the ammonia had been formed by the putrefaction of a part of their food, and that in reality the gastric juice of these animals is of an acid nature ‡.

The accounts which have been given of the gastric juice of man are so various, that it is not worth while to transcribe them. Sometimes it has been found of an acid nature, at other times not. The experiments of Spallanzani are sufficient to show that this acidity is not owing to the gastric juice, but to the food. He never found any acidity in the gastric juice of birds of prey, nor of serpents, frogs, and fishes. Crows gave an acidulous gastric juice only when fed on grain; and he found that the same observation holds with respect to dogs, herbivorous animals, and domestic fowls. Carnivorous birds threw up pieces of shells and coral without alteration; but these substances were sensibly diminished in the stomachs of hens, even when inclosed in perforated tubes. Spallanzani himself swallowed calcareous substances inclosed in tubes; and when he fed on vegetables and fruits, they were sometimes altered

* Scopoli, Macquer's *Dict.* † Ibid.
‡ Sennebier's *Observations on Gastric Juice.*

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and a little diminished in weight, just as if they had been put into weak vinegar; but when he used only animal food, they came out untouched. According to this philosopher, whose experiments have been by far the most numerous, the gastric juice is naturally neither acid nor alkaline. When poured on the carbonate of potash, it causes no effervescence.

Such are the results of the experiments on the juices taken from the stomach of animals. No conclusion can be drawn from them respecting the nature of the gastric juice. But from the experiments which have been made on the digestion of the stomach, especially by Spallanzani, the following facts are established.

Its effect on the food.

The gastric juice attacks the surface of bodies, unites to the particles of them, which it carries off, and cannot be separated from them by filtration. It operates with more energy and rapidity the more the food is divided, and its action is increased by a warm temperature. The food is not merely reduced to very minute parts; its taste and smell are quite changed; its sensible properties are destroyed, and it acquires new and very different ones. This juice does not act as a ferment; so far from] it, that it is a powerful antiseptic, and even restores flesh already putrefied. There is not the smallest appearance of such a process; indeed, when the juice is renewed frequently, as in the stomach, substances dissolve in it with a rapidity which excludes all idea of fermentation. Only a few air bubbles make their escape, which adhere to the elementary matter, and buoy it up to the top, and which are probably extricated by the heat of the solution.

With respect to the substances contained in the stomach, only two facts have been perfectly ascertained:

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Substances found in the stomach.

The first is, that the juice contained in the stomach of oxen, calves, sheep, invariably contains uncombined phosphoric acid, as Macquart and Vauquelin have demonstrated: The second, that the juice contained in the stomach, and even the inner coat of the stomach itself, has the property of coagulating milk and the serum of blood. Dr Young found that seven grains of the inner coat of a calf's stomach, infused in water, gave a liquid which coagulated more than 100 ounces of milk; that is to say, more than 6857 times its own weight; and yet, in all probability, its weight was not much diminished.

What the substance is which possesses this coagulating property, has not yet been ascertained; but it is evidently not very soluble in water: for the inside of a calf's stomach, after being steeped in water for six hours, and then well washed with water, still furnishes a liquor on infusion which coagulates milk *: And Dr Young found that a piece of the inner coat of the stomach, after being previously washed with water, and then with a diluted solution of carbonate of potash, still afforded a liquid which coagulated milk and serum.

It is evident, from these facts, that this coagulating substance, whatever it is, acts very powerfully; and that it is scarcely possible to separate it completely from the stomach. But we know at present too little of the nature of coagulation to be able to draw any inference from these facts. An almost imperceptible quantity of some substances seems to be sufficient to coagulate milk: For Mr Vaillant mentions, in his Travels in Africa, that

* Dr Young.

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a porcelain dish which he procured, and which had lain for some years at the bottom of the sea, possessed, in consequence, the property of coagulating milk when put into it; yet it communicated no taste to the milk, and did not differ in appearance from other cups.

It is probable that the saliva is of service in the conversion of food into chyme as well as the gastric juice. It evidently serves to dilute the food; and probably it may be serviceable also by communicating oxygen.

Chyme converted into chyle and excrement.

6. The chyme, thus formed, passes from the stomach into the intestines, where it is subjected to new changes, and at last converted into two very different substances, chyle and excrementitious matter.

Nature of chyle.

The *chyle* is a white-coloured liquid, very much resembling milk. It is exceedingly difficult to collect it in any considerable quantity, and for that reason it has never been accurately analysed. We know only in general that it resembles milk; containing, like it, an albuminous part capable of being coagulated, a serum, and globules which have a resemblance to cream*. It contains also different salts; and, according to some, a substance scarcely differing from the sugar of milk. Dr Charles Smith of New Jersey relates an instance of a dropsy of the abdomen, in which the liquid accumulated appears to have been chyle. The patient, a boy twelve years of age, was tapped twice, and each time between seven and eight quarts of liquid abstracted. Its colour was chalky-white, and resembled milk pretty nearly, both in its taste, smell, and appearance. On standing

* Fordyce on *Digestion*, p. 121.

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a night, it threw up a good cream, though not so much in proportion as cow's milk usually does *.

Its formation a chemical process.

7. Concerning the process by which chyle is formed from chyme, scarcely any thing is known. It does not appear that the chyme is precisely the same in all animals; for those which are herbivorous have a greater length of intestine than those which are carnivorous. It is certain that the formation of the chyle is brought about by a chemical change, although we cannot say precisely what that change is, or what the agents are by which it is produced. But that the change is chemical, is evident, because the chyle is entirely different, both in its properties and appearance, from the chyme. The chyme, by the action of the intestines, is separated into two parts, chyle and excrement: the first of which is absorbed by a number of small vessels called *lacteals*; the second is pushed along the intestinal canal, and at last thrown out of the body altogether.

After the chyme has been converted into chyle and excrement, although these two substances remain mixed together, it does not appear that they are able to decompose each other; for persons have been known seldom or never to emit any excrementitious matter *per anum* for years. In these, not only the chyle, but the excrementitious matter also, was absorbed by the lacteals; and the excrement was afterwards thrown out of the body by other outlets, particularly by the skin: in consequence of which, those persons have constantly that particular odour about them which distinguishes excrement. Now, in these persons it is evident that the

* *Phil. Mag.* ix. 16.

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chyle and excrement, though mixed together, and even absorbed together, did not act on each other; because these persons have been known to enjoy good health for years, which could not have been the case had the chyle been destroyed.

Use of the bile.

It has been supposed by some that the decomposition of the chyme, and the formation of chyle, is produced by the agency of the bile, which is poured out abundantly, and mixed with the chyme, soon after its entrance into the intestines. If this theory were true, no chyle could be formed whenever any accident prevented the bile from passing into the intestinal canal: but this is obviously not the case; for frequent instances have occurred of persons labouring under jaundice, from the bile ducts being stopped, either by gall-stones or some other cause, so completely, that no bile could pass into the intestines; yet these persons have lived for a considerable time in that state. Consequently digestion, and therefore the formation of chyle, must be possible, independent of bile.

The principal use of the bile seems to be to separate the excrement from the chyle, after both have been formed, and to produce the evacuation of the excrement out of the body. It is probable that these substances would remain mixed together, and that they would perhaps even be partly absorbed together, were it not for the bile, which seems to combine with the excrement, and by this combination to facilitate its separation from the chyle, and thus to prevent its absorption. Fourcroy supposes that the bile, as soon as it is mixed with the contents of the intestinal canal, suffers a decomposition: that its alkali and saline ingredients combine with the chyle, and render it more liquid,

while its albumen and resin combine with the excrementitious matter, and gradually render them less fluid *. From the late experiments of Berzelius on feces, detailed in the preceding Chapter, it cannot be doubted that the constituents of the bile are to be found in the excrementitious matter: So that the ingenious theory of Fourcroy is so far probable. The bile also stimulates the intestinal canal, and causes it to evacuate its contents sooner than it otherwise would do; for when there is a deficiency of bile the body is constantly costive.

8. The chyle, after it has been absorbed by the lacteals, is carried by them into a pretty large vessel, known by the name of the *thoracic duct*. Into the same vessel likewise is discharged a transparent fluid, conveyed by a set of vessels which arise from all the cavities of the body. These vessels are called *lymphatics*, and the fluid which they convey is called *lymph*. In the thoracic duct, then, the chyle and the lymph are mixed together. Chyle mixes with lymph,

Very little is known concerning the nature of the *lymph*, as it is scarcely possible to collect it in any quantity. It is colourless, has some viscidity, and is said to be specifically heavier than water. It is said to be coagulable by heat; if so, it contains albumen; and from its appearance it probably contains gelatine. Its quantity is certainly considerable, for the lymphatics are very numerous.

9. The chyle and lymph being thus mixed together, are conveyed directly into the blood vessels. The ef- And is conveyed to the lungs.

* Fourcroy, x. 48.

fect produced by their union in the thoracic duct is not known, but neither the colour nor external properties of the chyle are altered. In man, and many other animals, the thoracic duct enters at the junction of the left subclavian and carotid veins, and the chyle is conveyed directly to the heart, mixed with the blood, which already exists in the blood vessels. From the heart, the blood and chyle thus mixed together are propelled into the lungs, where they undergo farther changes.

Such are the phenomena of digestion, as far as they have been traced. The food is first conveyed to the stomach, where, by means of the gastric juice, it is converted into chyme. The chyme passes into the intestinal canal, where it is subjected to a new process, being gradually decomposed and converted into chyle and excrementitious matter, which, by means of the bile, are separated from each other. The excrementitious matter is evacuated, but the chyle is absorbed by the lacteals, and conveyed to the blood vessels and lungs. Let us now endeavour to trace the changes produced on it by these organs.

SECT. II.

OF RESPIRATION.

Respiration necessary.

The absolute necessity of respiration, or of something analogous, is known to every one; and few are ignorant that in man, and hot blooded animals, the or-

gan by which respiration is performed is the lungs. Now respiration consists in drawing a certain quantity of air into the lungs, and throwing it out again alternately. Whenever this function is suspended, even for a very short time, the animal dies.

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The fluid respired by animals is common atmospherical air; and it has been ascertained by experiment, that no other gaseous body with which we are acquainted can be substituted for it. All the known gases have been tried; but they all prove fatal to the animal which is made to breathe them. Gaseous bodies, as far as respiration is concerned, may be divided into two classes: 1. Unrespirable gases; 2. Respirable gases.

Unrespirable gases.

I. The gases belonging to the first class are of such a nature that they cannot be drawn into the lungs of an animal at all; the epiglottis closing spasmodically whenever they are applied to it. To this class belong carbonic acid, and probably all the other acid gases, as has been ascertained by the experiments of Pilatre de Rozier *. Ammoniacal gas belongs to the same class;

* *Jour. de Phys.* xxviii. 418.—Pilatre de Rozier went into a brewer's tub while full of carbonic acid gas evolved by fermentation. A gentle heat manifested itself in all parts of his body, and occasioned a sensible perspiration. A slight itching sensation constrained him frequently to shut his eyes. When he attempted to breathe, a violent feeling of suffocation prevented him. He sought for the steps to get out; but not finding them readily, the necessity of breathing increased, he became giddy, and felt a tingling sensation in his ears. As soon as his mouth reached the air he breathed freely, but for some time he could not distinguish objects; his face was purple, his limbs weak, and he understood with difficulty what was said to him. But these symptoms soon left him. He repeated the experiment often; and always found, that as long as he continued without breathing, he could speak and move about without inconvenience; but whenever he attempted to breathe, the feeling of suffocation came on.—Ibid. p. 422.

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for the lungs of animals suffocated by it were found b[y] Pilatre not to give a green colour to vegetable blues*.

Respirable gases, of four kinds.

II. The gases belonging to the second class may b[e] drawn into the lungs, and thrown out again witho[ut] any opposition from the respiratory organs; of cour[se] the animal is capable of respiring them. They m[ay] be divided into four subordinate classes: 1. The fi[rst]

1. Suffocate.

set of gases occasion death immediately, but produ[ce] no visible change in the blood. They occasion the an[i]mal's death merely by depriving him of air, in t[he] same way as he would be suffocated by being kept u[n]der water. The only gases which belong to this cl[ass] are *hydrogen* and *azotic*.—2. The second set of ga[ses]

2. Kill by occasioning changes in the blood.

occasion death immediately, but at the same time th[ey] produce certain changes in the blood, and therefore k[ill] not merely by depriving the animal of air, but by cer[]tain specific properties. The gases belonging to th[is] class are *carbureted hydrogen*, *sulphureted hydrogen*, *carbonic oxide*, and perhaps also *nitrous gas*.—3. T[he]

3. Support life imperfectly.

third set of gases may be breathed for some time wi[th]out destroying the animal, but death ensues at last, pr[o]vided their action be long enough continued. To th[is] class belong the nitrous oxide and oxygen gas‡.—

4. May be breathed without injury.

The fourth set may be breathed any length of ti[me] without injuring the animal. *Air* is the only gase[ous] body belonging to this class§.

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* *Jour. de Phys.* xxviii. 424.

† See Chausier's experiments, Ibid. lvi. 35.

‡ Perhaps also nitrous gas might have the same effect, if it coul[d be] breathed by an animal whose lungs contained no oxygen.

§ For by far the completest account of all the experiments hith[erto] made on the respiration of animals, the reader is referred to Dr Bom[]

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Oxygen necessary in respiration.

It has been long known that an animal can only breathe a certain quantity of air for a limited time; after which it becomes the most deadly poison, and produces suffocation as effectually as the most noxious gas, or a total absence of air. It was suspected long ago that this change is owing to the absorption of a part of the air; and Mayow made a number of very ingenious experiments in order to prove the fact. In 1757 Dr Black, by breathing through lime-water, ascertained that the air, when thrown out of the lungs, contained carbonic acid *. This discovery was still farther confirmed by Lavoisier in his first dissertation on respiration, published in the Memoirs of the French Academy for 1777. Priestley and Scheele demonstrated that the quantity of oxygen in atmospherical air is diminished by respiration. It was afterwards proved by Lavoisier, and many other philosophers, who confirmed and extended his facts, that no animal can live in air totally destitute of oxygen. Even fish, which do not sensibly respire, die very soon if the water in which they live be deprived of oxygen gas. Frogs, which can suspend their respiration at pleasure, die in about forty minutes, if the water in which they have been confined be covered over with oil †. Insects and worms, as Vauquelin has proved, exhibit precisely the same phenomena. They require air as well as other animals, and die like them if they be deprived of it. They diminish the quantity of oxygen in the air in

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excellent *Essay on Respiration*. Nor are the clearness, impartiality, and solid judgment of this author inferior to the extent of his information.

* Black's *Lectures*, ii. 87.

† Carradori, *Ann. de Chim*. xxix. 171.

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which they live, and give out, by respiration, the very same products as other animals. Worms, which are more retentive of life than most other animals, or at least not so much affected by poisonous gases, absorb every particle of the oxygen contained in the air in which they are confined before they die. Mr Vauquelin's experiments were made on the *gryllus viridissimus*, the *limax flavus*, and *helix pomatia* *.

The quantity of air respired differs very much in different animals. Man and hot-blooded animals are under the necessity of breathing constantly; whereas amphibious animals have a certain power over respiration, and can suspend the function altogether for a limited time. Dr Barclay has ascertained that these animals acquire a much greater command over their respiratory organs by habit. Fish do not breathe at all, and consume so little air, that the small portion of it held in solution by the water in which they swim is sufficient for them. It appears that the number of respirations made in a given time differ considerably in different men. Dr Hales reckons them at 20 in a minute. A man on whom Dr Menzies made experiments, breathed only 14 times in a minute. Mr Davy informs us that he makes between 26 and 27 in a minute. I myself make about 19 at an average. The average of all is 20. Now 20 in a minute make 28,800 in 24 hours.

Number of respirations.

Quantity of air respired.

The quantity of air drawn in and emitted at every respiration must differ considerably with the size of the man and the capacity of his lungs. Dr Menzies found

* *Ann. de Chim.* xii. 278.

that a man draws in at a medium 40 cubic inches of air at every inspiration. Dr Goodwin has concluded, from his experiments, that, after a complete expiration, the mean quantity of air which remains in the lungs amounts to 109 cubic inches; and Menzies has endeavoured to prove that, after an ordinary expiration, there remains 179. Mr Davy has concluded that his lungs, after a forced expiration, still retain 41 cubic inches of air; after a natural expiration they contain

118 cubic inches

After a natural inspiration 135

After a forced inspiration 254

By a full forced expiration, after a forced inspiration, he threw out .... 190 cubic inches

After a natural inspiration .. 78·5

After a natural expiration .. 67·5

Messrs Allen and Pepys have calculated, that, in an ordinary inspiration, 16·5 cubic inches of air are drawn into the lungs. In their experiments the average quantity of air thrown out of the lungs in an expiration amounted to 61 cubic inches, but the breathing was much fuller and slower than usual. In one case a forced expiration amounted to 166 cubic inches; in another to 204 cubic inches. From the experiments of the same gentlemen it appears, that the lungs of a stout man about five feet ten inches high after death contain nearly 100 cubic inches of air *.

Dr Menzies' estimate of an ordinary inspiration seems to approach nearest the average; but Dr Bostock has shown that his estimate of the capacity of the lungs is too low. Perhaps we shall not err very much if

* *Phil. Trans.* 1809.

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we suppose, with him, that the ordinary quantity of air contained in the lungs is 280 cubic inches; and that 40 inches, or $\frac{1}{7}$th of the whole, is drawn in and thrown out at every ordinary respiration. This, supposing 20 respirations in a minute, will make the quantity of air drawn in and thrown out of the lungs every minute amount to 800 inches; to 48,000 inches in the hour; and to 1,152,000 inches in 24 hours, which amounts to rather more than $52\frac{1}{2}$ lbs avoirdupois. If this estimate is too high, it is probably at least as near the truth as that of Allen and Pepys, which appears as much too low.

Let us now endeavour to trace the changes produced by respiration. These are of two kinds, namely, 1. The changes produced upon the air respired; 2. Changes produced upon the blood exposed to this air. Each of these naturally claims our attention.

Changes produced on the air respired.

I. For our knowledge of the changes produced upon the air by respiration, we are chiefly indebted to Priestley, Cigna, Menzies, Lavoisier and Seguin, Davy, Allen and Pepys. These changes are the following: 1. Part of the oxygen of the air respired disappears; 2. Carbonic acid gas is found in its place; 3. It is loaded with water in the state of vapour.

Change of bulk.

1. A considerable number of experiments have been made to determine the change of bulk which air undergoes by being respired. According to Davy, air, by a single inspiration and expiration, is diminished from $\frac{1}{70}$th to $\frac{1}{100}$th part of its bulk *. In the numerous and accurate experiments made by Allen and Pepys on

* Davy's *Researches*, p. 431.

a very large scale, the average diminution was little more than half a *per cent.*, and even this seems to have been owing rather to unavoidable inaccuracy than to real absorption. In the experiments of Berthollet, conducted also with very great care, the diminution varied from 0·69 to 3·70 *per cent.** If, with Dr Bostock, we take $\frac{1}{80}$th as the average diminution, and 40 inches as the quantity of air drawn into the lungs at each inspiration, then it will follow that half a cubic inch of the air disappears each time we respire. This in a day would amount to 14,400 cubic inches, which is rather more than eight cubic feet.

When air is breathed till the animal can support it no longer, the diminution which it undergoes is variously stated. Mr Davy found it to amount to $\frac{1}{18}$th of the whole air †; Lavoisier and Goodwyn to $\frac{1}{60}$th ‡; Allen and Pepys to $\frac{1}{12}$th §; and Crawford ||, on the other hand, found no diminution at all. These numbers vary so much from each other, and from the estimate from a single respiration, that it is impossible to avoid concluding the diminution to be different at different times. I was induced by a letter from Mr Dalton, in the summer of 1806, to make some experiments on the subject. In some cases I could perceive no diminution at all; in others it was perceptible. It was greatest when the animal was taken out repeatedly during the experiment, or when air was employed which was purer than that of the atmosphere. I am

* *Mem. d'Arcueil*, ii. 461.
† Davy's *Researches*, p. 435.
‡ Bostock on *Respiration*, p. 87.
§ *Phil. Mag.* xxxii. 254.
|| Crawford on *Heat*, p. 146.

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coincidence would dispose us to embrace this result as affording a near approximation to the truth. We may conclude, then, that in a day a man consumes rather more than 25 cubic feet of oxygen. Now, since the oxygen amounts only to about one-fifth of the atmosphere, it follows, that in a day, a man destroys, or renders unfit for supporting combustion and respiration, no less than 125 cubic feet of air. The result obtained by Messrs Allen and Pepys is somewhat less, or about 27·5 cubic inches per minute. And they think that in ordinary respiration the proportion consumed is much smaller.

Carbonic acid formed;

3. The air which is thrown out of the lungs contains in it a quantity of carbonic acid which did not exist in it previous to its being used for respiration. Dr Menzies conceived that the bulk of this gas is precisely equivalent to that of the oxygen consumed. This also was the result of the experiments of Dr Crawford. Lavoisier, in his experiments on the Guinea pig, found it somewhat less. In his first experiment he found the oxygen consumed, to the carbonic acid formed, as 20 to 16·5; in his second, as 20 to 17·3*. In his experiments on Seguin, in 1789, the oxygen consumed was to the bulk of carbonic acid formed nearly as 20 to 16·6; but in those that were made afterwards, the proportion of carbonic acid is diminished by nearly one-half. In Mr Davy's experiments, the bulk of carbonic acid formed corresponded very nearly with that of the oxygen consumed †; so that in this respect they coincided

* See the details, *Mem. Par.* 1780, p. 401.; *Ann. de Chim.* v. 261.; and in Bostock on *Respiration*, p. 79.

† Davy's *Researches*, p. 431.

Book V. with those of Crawford and Menzies. I was informed by Mr Dalton, in the summer of 1806, that he had satisfied himself, by a variety of experiments, that the bulk of carbonic acid gas formed was exactly equal to that of the oxygen gas consumed. On repeating the experiment with that particular view, I found that in some cases this took place very nearly; but upon the whole, the bulk of oxygen which disappeared was somewhat greater than that of the carbonic acid formed; but the difference varied considerably, and kept pace with the diminution of the bulk of air by respiration. Hence I consider it as owing to the abstraction of a part of the air by some other way than respiration. If this abstraction be allowed for, I have no doubt, from my own experiments, that the bulk of the carbonic acid formed by respiration is precisely equal to that of the oxygen which has disappeared. The absolute quantity it is difficult to state, as it depends upon a variety of circumstances. I am disposed to consider it, at an average, as approaching to 40,000 cubic inches in 24 hours, though probably somewhat under that quantity. Now, this quantity of carbonic acid contains little less than three quarters of a pound avoirdupois of carbon. Messrs Allen and Pepys found the carbonic acid formed exactly equal in bulk to the oxygen which had disappeared. It amounted in their experiments to about $27\frac{1}{2}$ cubic inches per minute, or 39,534 cubic inches in 24 hours, a quantity which contains above 11 ounces troy of solid carbon. Air thrown out of the lungs contained in their experiments about 8 *per cent.* of carbonic acid gas. In Berthollet's experiments, the carbonic acid gas form-

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ed varied from 5·53 to 13·82 *per cent*. But the animal was confined for several hours in the same air *.

Azote.

4. Dr Priestley concluded from his experiments, that not only the oxygen, but the azote also, of the air respired was diminished †. This opinion was still farther confirmed by Davy, who found the consumption of azote to amount to about $\frac{1}{7}$th of that of the oxygen ‡. Dr Henderson has lately made experiments with the same result, though the proportion of azote absorbed was rather less §. Upon repeating these experiments, I found likewise a loss of azote; but it was extremely inconstant, sometimes being scarcely perceptible, and at other times considerable. It kept pace with the diminution of the bulk of the air respired, and with the difference between the bulk of the oxygen consumed and the carbonic acid formed. Hence I am disposed to ascribe all of these differences to the same cause. I conceive that a portion of the air respired disappears without undergoing any change, and that this portion occasions the diminution of the azote, and the difference between the bulk of the carbonic acid formed and the oxygen consumed. What comes of this portion of air it is difficult to say; but I think it conceivable that the disappearing of such a portion may be confined to the unnatural circumstances occasioned by the experiment; that the difficulty of throwing out the air from the lungs in these circumstances may be such as to induce absorbents to act, and remove a portion which, in the ordinary situation of the lungs, would have been thrown

* *Mem. d'Arcueil*, ii. 461.

† Priestley, ii. 380.

‡ Davy's *Researches*, p. 433.

§ Nicholson's *Jour.* viii. 44.

apour actually emitted from the lungs. Supposing 0 inches of air to be drawn in at each inspiration, it vas easy to calculate, from Dalton's table, the weight f the vapour which it contained when emitted.

6. In ordinary cases of respiration, the oxygen, which disappears, is just balanced by the carbonic acid ormed, so that the bulk of the air continues unaltered: ut it appears from the experiments of Messrs Allen and Pepys, that when the same quantity of air is reathed backwards and forwards as long as possible, a greater quantity of oxygen disappears than can be accounted for by the carbonic acid formed. This oxygen is absorbed by the system. It diminishes the bulk of the air respired, and amounts to about $\frac{1}{72}$th of the whole air respired at an average.

7. When oxygen gas, nearly pure, is breathed, rather a greater quantity of carbonic acid is given out; for the air expired contains, at an average, above ten *per cent.* of that gas. It appears also from the experiments of Messrs Allen and Pepys, that a portion of the oxygen gas disappears, and then an equal bulk of azotic gas is found in its place. This substitution of azote is greatest at the commencement of the experiment, and diminishes as the respiration continues. It is difficult at present to account for this substitution. The quantity observed, amounting at an average to nearly 80 cubic inches, is too great to be ascribed to an error in the experiment. It can only be fully accounted for when we become acquainted with the composition of azote, which is still unknown; though, from the recent experiments of Davy and Berzelius, there can be no doubt that it is a compound.

Respiration of oxygen gas;

ture of the gases.	Gases before experiment.	Ditto after ditto.	Difference.	The fishes have Absorbed	Produced	Azote absorbed, the oxygen being 100.	Carb. acid produced, the oxygen absorbed being 100.	Number of fishes and time.
tal	175·0	135·1	39·9					Three tenches during 5 hours, 15 minutes.
ygen	52·1	5·6		46·5				
ote	115·9	95·8		20·1		43	57	
rbonic acid	7·0	33·7			26·7			
tal	524·0	404·0	119·6					Seven tenches during 6 hours.
ygen	155·9	44·0		111·9				
ote	347·1	249·5		97·6		87	80	
rbonic acid	21·0	110·9			89·9			
tal	524·0	453·0	71·0					Seven tenches during 8 hours.
ygen	155·9	10·5		145·4				
ote	347·1	289·5		57·6		40	91	
rbonic acid	21·0	153·0			132·0			
tal	483·0	345·5	137·5					One tench during 17 hours.
ygen	143·7	4·2		139·5				
ote	320·0	294·1		25·9		19		
rbonic acid	19·3	47·2			27·9		20	
tal	483·0	408·0	75·0					Three tenches during 7½ hours.
ygen	143·7	62·6		81·1				
ote	320·0	285·4		34·6		43		
rbonic	19·3	60·0			40·7		50	
tal	483·0	398·6	84·4					Three tenches during 5 hours.
ygen	143·7	40·0		103·7				
ote	320·0	246.6		73·4		71		
rbonic acid	19·3	112·0			92.7		89	
tal	483·0	372·5	110·5					Two tenches during 7 hours *.
ygen	143·7	37·8		105·9				
ote	320·0	252·9		67·1		63		
rbonic acid	19·3	81·8			62·5		59	

* The numbers in this table indicate cubic centimetres. A cubic centimetre is equal to 0·0610 of a cubic inch.

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The quantity of gas obtained from the Seine water, was at an average 0·0275 of its bulk, or not quite $\frac{1}{36}$ part; the average quantity of oxygen which this gas contained was 0·310.

From these experiments it appears, that the respiration of fishes differs very much from that of other animals. The oxygen is not merely converted into carbonic acid, as happens during the respiration of men and the larger animals; but a portion of it is absorbed and introduced into the system. A portion also of azote is absorbed. The quantity of air consumed by fishes is extremely small, when compared with that consumed by terrestrial animals. This will appear from the following table, in which the bulk of the air consumed, and of the carbonic acid formed in an hour, is stated in cubic inches.

Time.	Oxygen in the air after the experiments.	Number of fish.	Hours the experiment lasted.	Absorption in 1 hour in cubic inches.		Carbonic acid produced, in cubic inches.
				Oxygen.	Azote.	
28 Feb.	0·056	3	$5\frac{1}{4}$	0·0245	0·0106	0·0140
3 March	0·151	7	6	0·0221	0·0192	0·0177
7 March	0·034	7	$8\frac{1}{2}$			0·0185
11 March	0·017	1	17	0·0679	0·0126	0·0136
28 Feb.	0·178	3	$7\frac{1}{2}$	0·0298	0·0123	0·0150
24 Feb.	0·141	3	5	0·0575	0·0405	0·0512
20 Feb.	0·130	2	7	0·0635	0·0397	0·0370

From this table, compared with the facts stated in the preceding part of this section, it follows, that in a given time a man consumes 50,000 times as much oxygen gas as a tench. Yet the presence of this principle is equally necessary for the existence of both.

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Changes produced on the blood.

II. Let us now endeavour to ascertain the changes produced on the blood by respiration. The whole of the blood is propelled from the heart to the lungs, circulates through the vessels of that organ; and during that circulation it is exposed to the influence of the air which the animal is constantly drawing into the lungs. Now, certain changes are produced upon it by this action, which have been partly traced by the experiments of Priestley, Cigna, Fourcroy, Hassenfratz, Beddoes, Watt, and above all by those of Mr Davy. These changes, as far as we are acquainted with them, are the following: 1. It acquires a florid red colour, and the chyle disappears; 3. It loses a portion of carbon; 4. It emits water.

1. It has been long known that the blood which flows in the veins is of a dark reddish purple colour, whereas the arterial blood is of a florid scarlet colour. Lower observed that the colour of the venous blood was converted into that of arterial during its passage through the lungs. No chyle can be distinguished by its white colour in the blood after it has passed through the lungs. The changes, then, which take place upon the appearance of the blood are two: 1. It acquires a florid red colour; 2. The chyle totally disappears. Lower himself knew that the change was produced by the air, and Mayow attempted to prove that it was by absorbing a part of the air. But it was not till Dr Priestley discovered that venous blood acquires a scarlet colour

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when put in contact with oxygen gas, and arterial blood a dark red colour when put in contact with hydrogen gas; or, which is the same thing, that oxygen gas instantly gives venous blood the colour of arterial; and hydrogen, on the contrary, gives arterial blood the colour of venous blood—it was not till then that philosophers began to attempt any thing like an explanation of the phenomena of respiration.

Action of different gases on blood.

The blood is a fluid of so complex a nature that it is not easy to ascertain the changes produced in it by exposure to different gases out of the body; and even if that could be done, we have no method of proving that the effects of these gaseous bodies upon the coagulated blood are the same as they would be on the blood in its natural state, circulating in the vessels of a living animal. The facts which have been ascertained are the following:

1. Oxygen,

1st, It appears from the experiments of Priestley, Girtanner, and Hassenfratz, that when venous blood is exposed to oxygen gas confined over it, the blood instantly assumes a scarlet colour. Mr Davy could not perceive any sensible diminution of the bulk of the gas.

2. Air,

2d, The same change of colour takes place when blood is exposed to common air. In this case a quantity of carbonic acid gas is formed, and a quantity of oxygen gas, exactly equal to it in bulk, disappears; making allowance for the small quantity of carbonic acid, which we may suppose to be absorbed by the blood itself.

3. Azotic,

3d, Venous blood exposed to the action of azotic gas continues unaltered in colour; neither does any perceptible diminution of the gas ensue.

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4th, Venous blood exposed to the action of nitrous gas becomes of a deep purple, and about $\frac{1}{8}$th of the gas is absorbed. 4. Nitrous,

5th, Venous blood exposed to nitrous oxide becomes of a brighter purple, especially on the surface, and a considerable portion of the gas is absorbed. 5. Nitrous oxide,

6th, Venous blood exposed to carbonic acid gas becomes of a brownish red colour, much darker than usual, and the gas is slightly diminished in bulk. 6. Carbonic acid,

7th, Carbureted hydrogen gas gives venous blood a fine red colour, a shade darker than oxygen gas does, as was first observed by Dr Beddoes, and at the same time a small portion of the gas is absorbed. This gas has the property of preventing, or at least greatly retarding, the putrefaction of blood, as was first observed by Mr Watt *. 7. Carbureted hydrogen.

8th, When arterial blood is put in contact with azotic gas, or carbonic acid gas, it gradually assumes the dark colour of venous blood, as Dr Priestley found †. The same philosopher also observed, that arterial blood acquired the colour of venous blood when placed *in vacuo* ‡. Consequently this alteration of colour is owing to some change which takes place in the blood itself, independent of any external agent. Arterial blood darkened by azotic and carbonic acid gas;

The arterial blood becomes much more rapidly and deeply dark coloured when it is left in contact with hydrogen gas placed above it §. We must suppose therefore that the presence of this gas accelerates and in-

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* Davy's *Researches*, p. 380.

† Priestley, iii. 363.

‡ Ibid. and *Ann. de Chim.* ix. 269.

§ Fourcroy, Ibid. vii. 149.

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creases the change, which would have taken place upon the blood without any external agent.

By rest,

9th, If arterial blood be left in contact with oxygen gas, it gradually assumes the same dark colour which it would have acquired *in vacuo*, or in contact with hydrogen; and after this change oxygen can no longer restore its scarlet colour *. Therefore it is only upon a part of the blood that the oxygen acts; and after this part has undergone the change which occasions the dark colour, the blood loses the power of being affected by oxygen.

And by oxymuriatic acid.

10th, Mr Hassenfratz poured into venous blood a quantity of oxymuriatic acid; the blood was instantly decomposed, and assumed a deep and almost black colour. When he poured common muriatic acid into blood, the colour was not altered †. Now oxymuriatic acid has the property of giving out its oxygen readily; consequently the black colour was owing to the instant combination of a part of the blood with oxygen.

Theory of Priestley.

2. Dr Priestley, the first of the modern chemists who turned his attention to respiration, concluded from some of his earliest experiments, that the blood, as it passed through the lungs, gave out phlogiston to the air, which was expired loaded with that substance; and of course that the purpose of respiration was to free the blood of phlogiston. Lavoisier soon after ascertained with more precision the changes which the air undergoes during respiration; and he formed a theory in order to explain that function, assuming as its basis that all the

* Fourcroy, ix. 268. † Ibid.

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changes on the air inspired are produced in the lungs; and of course, that all the new substances expired are formed in the lungs. According to him, the blood absorbs no air in the lungs; but it gives out hydrogen and carbon, which, combining with the oxygen of the air inspired, form water and carbonic acid. This theory was adopted by La Place, Crawford, Gren, and Girtanner, with a small variation. Indeed it does not differ, except in detail, from the original hypothesis of Dr Priestley, that the use of respiration is to rid the blood of phlogiston; for if we substitute carbon and hydrogen for phlogiston, the two theories precisely agree. Mr Lavoisier attempted not to prove its truth; he only tried to show that the oxygen absorbed corresponds exactly with the quantity of oxygen contained in the carbonic acid and the water emitted.

Modified by Lavoisier.

A different theory was afterwards proposed by Mr De La Grange. According to this philosopher, the oxygen gas, which disappears, combines with the blood as it passes through the lungs; and at the instant of this combination there is set free from the blood a quantity of carbonic acid gas and of water, which are thrown out along with the air expired. This theory was adopted and illustrated by Mr Hassenfratz. In the first and second Editions of this Work I embraced this theory, modified a little by the experiments of Davy. A letter which I received from Mr Dalton, in the summer of 1806, combating this theory, and defending that of Crawford, induced me to examine it more narrowly; and the result of a set of experiments, which I immediately undertook, convinced me that Mr Dalton's objections were well founded. The carbonic acid formed, I consider as exactly equal to the bulk of the oxygen

Theory of La Grange.

Crawford's theory seems correct.

this *must* be formed there, because it does not exist previously. Now, one great end of respiration must undoubtedly be to assist this decomposition of chyle and complete formation of blood. Chap. III.

It follows, from the experiments of Fourcroy formerly enumerated, that fibrin contains more azote, and less carbon, than any of the other ingredients of the blood, and consequently also than any of the ingredients of the chyle. In what manner the chyle, or a part of it, is converted into fibrin, it is impossible to say: we are not sufficiently acquainted with the subject to be able to explain the process. But we can see, at least, that carbon must be abstracted from that part of the chyle which is to be converted into fibrin. Hence, as the process of blood-making advances, there must be a greater and greater redundancy of carbon in the liquid. Unless this redundancy were removed, the process could not go on, and probably the whole would run into putrefaction. We may conclude, then, that one great use of respiration is to abstract this carbon, by forming with it carbonic acid. How this is performed, indeed, it is impossible at present to explain; but the fact is undoubted.

Animal heat.

But the abstraction of carbon is not the only advantage gained by respiration: the *temperature* of all animals depends upon it. It has been long known, that those animals which do not breathe have a temperature but very little superior to the medium in which they live. This is the case with fishes and many insects. Man, on the contrary, and quadrupeds which breathe, have a temperature considerably higher than the atmosphere: that of man is 98°. Birds, who breathe in proportion a still greater quantity of air than man, have

a temperature equal to 103° or 104°. It has been proved, that the temperature of all animals is proportional to the quantity of air which they breathe in a given time.

These facts are sufficient to demonstrate that the heat of animals depends upon respiration. But it was not till Dr Black's doctrine of latent heat became known to the world, that any explanation of the cause of the temperature of breathing animals was attempted. The illustrious philosopher, whose discoveries form the basis upon which all the scientific part of chemistry has been reared, saw at once the light which his doctrine of latent heat threw upon this part of physiology, and he applied it very early to explain the temperature of animals.

Dr Black's theory.

According to him, part of the latent heat of the air inspired becomes sensible; and of course the temperature of the lungs, and the blood that passes through them, must be raised; and the blood, thus heated, communicates its heat to the whole body. This opinion was ingenious, but it was liable to an unanswerable objection: for if it were true, the temperature of the body ought to be greatest in the lungs, and to diminish gradually as the distance from the lungs increases; which is not true. The theory, in consequence, was abandoned even by Dr Black himself; at least he made no attempt to support it.

Theory of Crawford.

Dr Crawford, who considered all the changes operated by respiration as taking place in the lungs, accounted for the origin of the animal heat almost precisely in the same manner with Dr Black. According to him, the oxygen gas of the air combines in the *lungs* with the carbon emitted by the blood. During this combi-

nation, the oxygen gives out a great quantity of caloric, with which it had been combined; and this caloric is not only sufficient to support the temperature of the body, but also to carry off the new-formed water in the state of vapour, and to raise considerably the temperature of the air inspired. According to this philosopher, then, the whole of the caloric which supports the temperature of the body is evolved in the lungs. His theory accordingly was liable to the same objection with Dr Black's; but Dr Crawford obviated it in the following manner: He found that the specific caloric of arterial blood was 1·0300, while that of venous blood was only 0·8928. Hence he concluded, that the instant venous blood is changed into arterial blood, its specific caloric increases; consequently it requires an additional quantity of caloric to keep its temperature as high as it had been while venous blood. This addition is so great, that the whole new caloric evolved is employed: therefore the temperature of the lungs must necessarily remain the same as that of the rest of the body. During the circulation, arterial blood is gradually converted into venous; consequently its specific caloric diminishes, and it must give out heat. This is the reason that the temperature of the extreme parts of the body does not diminish. This theory is extremely ingenious, and accounts for the whole phenomena in a much more satisfactory manner than any other which has been proposed.

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SECT. III.

OF THE ACTION OF THE KIDNEYS.

THUS we have reason to suppose that chyle and lymph are converted into blood during the circulation: but besides the lungs and arteries, there is another organ, the sole use of which is also to produce some change or other in the blood, which renders it more complex, and more proper for the various purposes to which it is applied. This organ is the KIDNEY.

A very great proportion of blood passes through the kidneys; indeed we have every reason to conclude that the whole of the blood passes through them very frequently. These organs separate the urine from the blood, to be afterwards evacuated without being applied to any purpose useful to the animal.

Action of the kidneys necessary.

The kidneys are absolutely necessary for the continuance of the life of the animal; for it dies very speedily when they become by disease unfit to perform their functions: therefore the change which they produce in the blood is a change necessary for qualifying it to answer the purposes for which it is intended.

As the urine is immediately excreted, it is evident that the change which the kidneys perform is intended solely for the sake of the blood. It is not merely the abstraction of a quantity of water and of salts, accumulated in the blood, which the kidney performs. A chemical change is certainly produced, either upon the whole blood, or at least on some important part of it;

It changes the nature of the blood.

for there are two substances found in the urine which do not exist in the blood. These two substances are urea and uric acid. They are formed, therefore, in the kidneys; and as they are thrown out, after being formed, without being applied to any useful purpose, they are certainly not formed in the kidneys for their own sake. Some part of the blood, then, must be decomposed in the kidney, and a new substance, or new substances, must be formed; and the urea and uric acid must be formed at the same time, in consequence of the combined action of the affinities which produce the change on the blood; and being useless, they are thrown out together with a quantity of water and salts, which, in all probability, were useful in bringing about the changes which take place in the arteries and in the kidneys, but which are no longer of any service after these changes are brought about.

The changes operated upon the blood in the kidneys are at present altogether unknown; but they must be important. Provided the method of analysing animal substances were so far perfected as to admit of accurate conclusions, considerable light might be thrown upon this subject, by analysing with care a portion of blood from the emulgent vein and artery separately, and ascertaining precisely in what particulars they differ from each other.

by Bryan Robertson and Rye; and in Carolina by Lining. The result of all these experiments has been collected by Haller; but it gives us no precise estimate of the amount of the transpiration, since these philosophers have not distinguished between what is lost by the skin and by the lungs. Lavoisier and Seguin alone have attempted to ascertain the amount of the matter perspired through the skin. A bag composed of varnished silk, and perfectly air-tight, was procured, within which Seguin, who was usually the subject of experiment, was enclosed, and the bag was closed exactly over his head. There was a slit in the bag opposite to his mouth, and the edges of this slit were accurately cemented round the mouth by means of a mixture of turpentine and pitch. Thus every thing emitted by the body was retained in the bag, except what made its escape from the lungs by respiration. By weighing himself in a delicate balance at the commencement of the experiment, and again after he had continued for some time in the bag, the quantity of matter carried off by respiration was ascertained. By weighing himself without this varnished covering, and repeating the operation after the same interval of time had elapsed as in the former experiment, he ascertained the loss of weight occasioned by perspiration and respiration. By subtracting from this sum the loss of weight indicated by the first experiment, he obtained the quantity of matter which made its escape by perspiration in a given time. The following facts were ascertained by these experiments:

1. The maximum of matter perspired in a minute amounted to 26·25 grains troy; the minimum to nine grains: which gives 17·63 grains at a medium in the

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minute, or 52·89 ounces in the 24 hours. This quantity differs less than might have been expected from the result of former experiments made by Dodart, Keil, Rye, &c.

2. The quantity perspired is increased by drink, but not by solid food.

3. Perspiration is at its minimum immediately after a repast. It reaches its maximum during digestion*.

The quantity of matter perspired differs very considerably according to circumstances. It has been shown to be greatest in hot weather, and in hot climates, and after great exercise; and its relation to the quantity of urine has been long known. When the matter perspired is great, the quantity of urine is small, and vice *versa*.

Substances perspired.

To ascertain the substance thus emitted by perspiration is a difficult task, because it passes off invisibly, and in small quantities at a time. It has, notwithstanding, been ascertained, that water, carbon, and an oily matter, are emitted; and that acetic acid, phosphate of lime, and even urea, are sometimes emitted through the skin †.

It has been supposed that the skin has the property of *absorbing moisture* from the air; but this opinion has not been confirmed by experiments, but rather the contrary.

Whether the skin absorbs moisture.

The chief arguments in favour of the absorption of the skin have been drawn from the quantity of moisture discharged by urine being, in some cases, not only greater than the whole drink of the patient, but even

* Fourcroy, ix. 198. † See the preceding Chapter, Sect. 24.

than the whole of his drink and food. But it ought to be remembered that, in diabetes, the disease here alluded to, the weight of the body is continually diminishing, and therefore part of it must be constantly thrown off. Besides, it is scarcely possible in that disease to get an accurate account of the food swallowed by the patients; and in those cases where very accurate accounts have been kept, and where deception was not so much practised, the urine was found not to exceed the quantity of drink *. In a case of diabetes, related with much accuracy by Dr Gerard, the patient was bathed regularly during the early part of the disease in warm water, and afterwards in cold water: he was weighed before and after bathing, and no sensible difference was ever found in his weight †. Consequently, in that case, the quantity absorbed, if any, must have been very small.

It is well known that thirst is much alleviated by cold bathing. By this plan Captain Bligh kept his men cool and in good health during their very extraordinary voyage across the South Sea. This has been considered as owing to the absorption of water by the skin. But Dr Currie had a patient who was wasting fast for want of nourishment, a tumor in the æsophagus preventing the possibility of taking food, and whose thirst was always alleviated by bathing; yet no sensible increase of weight, but rather the contrary, was perceived after bathing. It does not appear, then, that in either of these cases water was absorbed.

Farther, Seguin has shown that the skin does not ab-

* See Rollo on *Diabetes*. † Ibid. ii. 73.

possible, then, that water, when in the state of vapour, or when dissolved in air, may be absorbed, although water, while in the state of water, may be incapable of pervading the cuticle. The experiments, therefore, which have hitherto been made upon the absorption of the skin, are insufficient to prove that air and vapour cannot pervade the cuticle, provided there be any facts to render the contrary supposition probable.

Now, that there are such facts cannot be denied. I shall not indeed produce the experiment of Van Mons as a fact of that kind, because it is liable to objections, and at best is very indecisive. Having a patient under his care who, from a wound in the throat, was incapable for several days of taking any nourishment, he kept him alive during that time by applying to the skin, in different parts of the body, several times a-day, a sponge dipt in wine or strong soup *. A fact mentioned by Dr Watson is much more important, and much more decisive. A lad at Newmarket, who had been almost starved in order to bring him down to such a weight as would qualify him for running a horse race, was weighed in the morning of the race day; he was weighed again an hour after, and was found to have gained 30 ounces of weight; yet in the interval he had only taken half a glass of wine. Here absorption must have taken place, either by the skin, or lungs, or both. The difficulties in either case are the same; and whatever renders absorption by one probable, will equally strengthen the probability that absorption takes place by the other †.

* *Phil. Mag.* vi. 95.

† Watson's *Chemical Essays*, iii. 101.—The Abbé Fontana also found

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SECT. V.

OF ASSIMILATION.

WE have now seen the progress of digestion, and the formation of blood, as far at least as we are acquainted with it. But to what purposes is this blood employed, which is formed with so much care, and for the formation of which so great an apparatus has been provided? It answers two purposes. The parts of which the body is composed, bones, muscles, ligaments, membranes, &c. are continually changing. In youth they are increasing in size and strength, and in mature age they are continually acting, and consequently continually liable to waste and decay. They are often exposed to accidents, which render them unfit for performing their various functions; and even when no such accident happens, it seems necessary for the health of the system that they should be every now and then renewed. Materials therefore must be provided for repairing, increasing, or renewing all the various organs of the body; phosphat of lime and gelatine for the bones, fibrin for the mus-

Blood answers two purposes: 1. Supplies the waste of the system.

that, after walking in moist air for an hour or two, he returned home some ounces heavier than he went out, notwithstanding he had suffered considerable evacuation from a brisk purge purposely taken for the experiment. This increase, indeed, might be partly accounted for by the absorption of moisture by his clothes.

cles, albumen for the cartilages and membranes, &c. Accordingly all these substances are laid up in the blood; and they are drawn from that fluid, as from a storehouse, whenever they are required. The process by which the different ingredients of the blood are made part of the various organs of the body is called ASSIMILATION.

Assimilation.

Over the nature of assimilation the thickest darkness still hangs: there is no key to explain it, nothing to lead us to the knowledge of the instruments employed. Facts, however, have been accumulated in sufficient numbers to put the existence of the process beyond the reach of doubt. The healing, indeed, of every fractured bone, and every wound of the body, is a proof of its existence, and an instance of its action.

Every assimilating organ produces a specific change,

Every organ employed in assimilation has a peculiar office; and it always performs this office whenever it has materials to act upon, even when the performance of it is contrary to the interest of the animal. Thus the stomach always converts food into chyme, even when the food is of such a nature that the process of digestion will be retarded rather than promoted by the change. If warm milk, for instance, or warm blood, be thrown into the stomach, they are always decomposed by that organ, and converted into chyme; yet these substances are much more nearly assimilated to the animal before the action of the stomach than after it. The same thing happens when we eat animal food.

And no other.

On the other hand, a substance introduced into an organ employed in assimilation, if it has undergone precisely the change which that organ is fitted to produce, is not acted upon by that organ, but passed on unalter-

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ed to the next assimilating organ. Thus it is the office of the intestines to convert chyme into chyle. Accordingly, whenever chyme is introduced into the intestines, they perform their office, and produce the usual change; but if chyle itself be introduced into the intestines, it is absorbed by the lacteals without alteration. The experiment, indeed, has not been tried with true chyle, because it is scarce possible to procure it in sufficient quantity ; but when milk, which resembles chyle pretty accurately, is thrown into the jejunum, it is absorbed unchanged by the lacteals *.

Again, the office of the blood-vessels, as assimilating organs, is to convert chyle into blood. Chyle, accordingly, cannot be introduced into the arteries without undergoing that change ; but *blood* may be introduced from another animal without any injury, and consequently without undergoing any change. This experiment was first made by Lower, and it has since been very often repeated.

Also, if a piece of fresh muscular flesh be applied to the muscle of an animal, they adhere and incorporate without any change, as has been sufficiently established by the experiments of Mr J. Hunter ; and Buvina has ascertained, that fresh bone may, in the same manner, be engrafted on the bones of animals of the same or of different species †.

Foreign substances may be incorporated with the body.

In short, it seems to hold, at least as far as experiments have hitherto been made, that foreign substances may be incorporated with those of the body, provided they be precisely of the same kind with those to which

* Fordyce on *Digestion*, p. 189. † *Phil. Mag.* vi. 302.

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they are added, whether fluid or solid. Thus chyle may be mixed with chyle, blood with blood, muscle with muscle, and bone with bone. The experiment has not been extended to the other animal substances, the nerves, for instance; but it is extremely probable that it would hold with respect to them also.

On the other hand, when substances are introduced into any part of the body which are not the same with that part, nor the same with the substance upon which that part acts, provided they cannot be thrown out readily, they destroy the part, and perhaps even the animal. Thus foreign substances introduced into the blood very soon prove fatal; and introduced into wounds of the flesh or bones, they prevent these parts from healing.

Powers of the assimilating organs limited.

Although the different assimilating organs have the power of changing certain substances into others, and of throwing out the useless ingredients, yet this power is not absolute, even when the substances on which they act are proper for undergoing the change which the organs produce. Thus the stomach converts food into chyme, the intestines chyme into chyle, and the substances which have not been converted into chyle are thrown out of the body. If there happen to be present in the stomach and intestines any substance which, though incapable of undergoing these changes, at least by the action of the stomach and intestines, yet has a strong affinity, either for the whole chyme and chyle, or for some particular part of it, and no affinity for the substances which are thrown out, that substance passes along with the chyle, and in many cases continues to remain chemically combined with the substance to which it is united in the stomach, even after that substance

Book V.

has been completely assimilated, and made a part of the body of the animal. Thus there is a strong affinity between the colouring matter of madder and phosphate of lime. Accordingly, when madder is taken into the stomach, it combines with the phosphate of lime of the food, passes with it through the lacteals and blood vessels, and is deposited with it in the bones, as was proved by the experiments of Duhamel. In the same manner, musk, indigo, &c. when taken into the stomach, make their way into many of the secretions.

Assimilation a chemical process;

These facts show us that assimilation is a chemical process from beginning to end; that all the changes are produced according to the laws of chemistry; and that we can even derange the regularity of the process by introducing substances whose mutual affinities are too strong for the organs to overcome.

It cannot be denied, then, that the assimilation of food consists merely in a certain number of chemical decompositions which that food undergoes, and the consequent formation of certain new compounds. But are the *agents* employed in assimilation merely chemical agents? We cannot produce any thing like these changes on the food out of the body, and therefore we must allow that they are the consequence of the action of the animal organs. But this action, it may be said, is merely the secretion of particular juices, which have the property of inducing the wished-for change upon the food: and this very change would be produced out of the body, provided we could procure these substances, and apply them in proper quantity to the food. If this supposition be true, the specific action of the vessels consists in the secretion of certain substances; consequently the cause of this secretion is the [illegible] of it

Chap. III.

assimilation. Now, can the *cause* of this secretion be shown to be merely a chemical agent? Certainly not. For in the stomach, where only this secretion can be shown to exist, it is not always the same, but varies according to circumstances. Thus eagles at first cannot digest grain, but they may be brought to do it by persisting in making them use it as food. On the contrary, a lamb cannot at first digest animal food, but habit will also give it this power. In this case, it is evident that the gastric juice changes according to circumstances.

But the agent not chemical.

The presence of some agent, different from a mere chemical power, will be still more evident, if we consider the immunity of the stomach of the living animal during the process of digestion. The stomach of animals is as fit for food as any other substance. The gastric juice, therefore, must have the same power of acting on it, and of decomposing it, that it has of acting on other substances; yet it is well known that the stomach is not affected by digestion while the animal retains life; though, as Mr Hunter ascertained, the very gastric juice which the living stomach secretes, often dissolves the stomach itself after death. Now what is the power which prevents the gastric juice from acting on the stomach during life? Certainly neither a chemical nor mechanical agent, for these agents must still retain the same power after death. We must, then, of necessity conclude, that there exists in the animal an agent very different from chemical and mechanical powers, since it controuls these powers according to its pleasure. These powers, therefore, in the living body, are merely the servants of this superior agent, which directs them so as to accomplish always one par-

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ticular end. This agent seems to regulate the chemical powers, chiefly by bringing only certain substances together which are to be decomposed, and by keeping at a distance those substances which would interfere with, or diminish, or spoil the product, or injure the organ; and we see that this separation is always attended to even when the substances are apparently mixed together: For the very same products are not obtained, which would be obtained by mixing the same substances together out of the body, that are produced by mixing them in the body; consequently all the substances are not left at full liberty to obey the laws of their mutual affinities. The superior agent, however, is not able to exercise an unlimited authority over the chemical powers; sometimes they are too strong for it: some substances, accordingly, as madder, make their way into the system; while others, as arsenic, decompose and destroy the organs of the body themselves.

But it is not in digestion alone that this superior agent makes the most wonderful display of its power; it is in the last part of assimilation that our admiration is most powerfully excited. How comes it that the precise substances wanted are always carried to every organ of the body? How comes it that fibrin is always regularly deposited in the muscles, and phosphate of lime in the bones? And what is still more unaccountable, how comes it that prodigious quantities of some one particular substance are formed and carried to a particular place, in order to supply new wants which did not before exist? A bone, for example, becomes diseased and unfit for the use of the animal; a new bone therefore is formed in its place, and the old one is

carried off by the absorbents. In order to form this new bone, large quantities of phosphate of lime are deposited in a place where the same quantity was not before necessary. Now, who informs this agent that an unusual quantity of phosphate of lime is necessary, and that it must be carried to that particular place? Or, granting, as is most probable, that the phosphate of lime of the old bone is partly employed for this purpose, who taught this agent that the old bone must be carried off, new-modelled, and deposited and assimilated anew? The same wonders take place during the healing of every wound, and the renewing of every diseased part.

But neither in this case is the power of this agent over the chemical agents which are employed absolute. We may prevent a fractured bone from healing, by giving the patient large quantities of acids. And unless the materials for new-wanted substances be supplied by the food, they cannot in many cases be formed at all. Thus the canary bird cannot complete her eggs unless she be furnished with lime.

Nature of this agent.

As this agent which characterises living bodies does not appear to act according to the principles of chemistry, any inquiry into its nature would be foreign to the subject of this Work. Physiologists have given it the name of the *living* or *animal* principle; and to them I beg leave to refer the reader.

2. Blood furnishes the materials of secretion.

Besides the different organs of the body, the blood is also employed in forming all the different secretions which are necessary for the purposes of the animal economy. These have been enumerated in the last Chapter. The process is similar to that of assimilation, and undoubtedly the agents in both cases are the same; but

we are equally ignorant of the precise manner in which secretion is performed as we are of assimilation.

Animals decay and die.

After these functions have gone on for a certain time, which is longer or shorter according to the nature of the animal, the body gradually decays, at last all its functions cease completely, and the animal dies. The cause of this must appear very extraordinary, when we consider the power which the animal has of renewing its decayed parts; for it cannot be doubted that death proceeds, in most cases at least, from the body becoming incapable of performing its functions. But if we consider that this power is limited, and that it must cease altogether when those parts of the system begin to decay which are employed in preparing materials for future assimilation, our surprise will, in some measure, cease. It is in these parts, in the organs of digestion and assimilation, accordingly, that this decay usually proves fatal. The decay in other parts destroys life only when the waste is so rapid that it does not admit of repair.

What the reason is that the decay of the organs causes death, or, which is the same thing, causes the living principle either to cease to act, or to leave the body altogether, it is perfectly impossible to say, because we know too little of the nature of the living principle, and of the manner in which it is connected with the body. The last is evidently above the human understanding; but many of the properties of the living principle have been discovered: and were the facts already known properly arranged, and such general conclusions drawn from them as their connection with each other fully warrant, a degree of light would be thrown

upon the animal economy, which those who have not attended to the subject are not aware of.

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No sooner is the animal dead, than the chemical and mechanical agents, which were formerly servants, usurp the supreme power, and soon decompose and destroy that very body which had been in a great measure reared by their means. But the changes which take place upon animal bodies after death, are too important to be passed over slightly. They shall therefore form the subject of the next Chapter.

CHAP. IV.

OF THE DECOMPOSITION OF ANIMAL BODIES.

THE rapidity with which animal bodies undergo decomposition, and the disgusting fetor which accompanies this decomposition, have long been considered as some of their most striking peculiarities. This spontaneous destruction is denominated *putrefaction*. Considerable attention has been paid to it by chemists. Becher and Stahl have described with fidelity the phenomena with which it is attended, and the circumstances necessary for its taking place. Several curious remarks on it were made by Boyle and Beale *. To Sir John Pringle we are indebted for some important experiments on the method of retarding putrefaction †; neither are the experiments of Dr Macbride less valuable, though the consequences which he drew from them were erroneous. We are indebted also to Crell and Priestley for many valuable facts; and to Berthollet and Lavoisier for the first attempts to determine the real changes

* *Phil. Trans.* iv. 1135.

† Ibid. xlvi. 480. &c.

which take place, and the manner in which the new products which appear during putrefaction are formed. But notwithstanding the labours of these philosophers, and of many others, much is still wanting to enable us to trace the complicated changes which take place during putrefaction, and to account for them in a satisfactory manner.

Conditions requisite for putrefaction.

It has been ascertained long ago, that putrefaction never takes place in those animal substances which contain only two or three ingredients, such as oils, resins, sugar; they must always be more complicated in their texture: and perhaps in all cases a mixture of two or more compound bodies is necessary for speedy decomposition. But however complicated the animal substance may be, it does not putrefy unless moisture be present; for dry animal substances are not susceptible of alteration. A certain degree of heat is also necessary. Animal bodies may be kept without decomposing for any length of time at the freezing temperature. In general, the higher the temperature the more rapid is the putrefaction, provided the heat be not great enough to reduce the animal body to dryness. It has been observed, too, that putrefaction advances with more rapidity in the open air; but exposure to the air is not necessary, though it modifies the decomposition.

Putrefaction in air.

When these conditions are observed, and dead animal matter is left to itself, its colour becomes gradually paler, and its consistence diminishes: if it be a solid part, such as flesh, it softens, and a serous matter sweats out, whose colour quickly changes; the texture of the part becomes relaxed, and its organization is destroyed; it acquires a disagreeable smell; the substance gradually sinks down, and is diminished in bulk; its smell

Book V.

becomes strongly ammoniacal. If the subject be contained in a close vessel, the progress of putrefaction at this stage seems to slacken ; no other smell but that of a pungent alkali is perceived ; the matter effervesces with acids, and converts syrup of violets to a green. But if the communication with the air be admitted, the urinous exhalation is dissipated, and a peculiar putrid smell is spread around with a kind of impetuosity ; a smell of the most insupportable kind, which lasts a long time, and pervades every place, affecting the bodies of living animals after the manner of a ferment, capable of altering the fluids : this smell is corrected, and as it were confined by ammonia. When the latter is volatilized, the putrefactive process becomes active a second time, and the substance suddenly swells up, becomes filled with bubbles of air, and soon after subsides again. Its colour changes, the fibrous texture of the flesh being then scarcely distinguishable ; and the whole is changed into a soft brown or greenish matter, of the consistence of a poultice, whose smell is faint, nauseous, and very active on the bodies of animals. The odorant principle gradually loses its force, the fluid portion of the flesh assumes a kind of consistence, its colour becomes deeper, and it is finally reduced into a friable matter, rather deliquescent : which being rubbed between the fingers, breaks into a coarse powder like earth. This is the last state observed in the putrefaction of animal substances ; they do not arrive at this term but at the end of a considerable time *.

Products.

During this decomposition a variety of gaseous bo-

* Fourcroy.

Chap. IV.

dies are emitted: these vary according to the substance exposed to putrefaction; but they consist chiefly of hydrogen gas, holding sulphur, phosphorus, and carbon in solution; of ammonia, water, and carbonic acid, and perhaps also of azotic gas. Nitric acid seems in some cases to be formed and emitted. The earthy-like residuum, which remains after the decomposition is completed, consists of the fixed parts of the animal substance, mixed with charcoal, oil, and ammonia. Thus it appears that putrefaction consists in a total decomposition of the animal body; the elements of which combine together two and two, and thus form a new set of less complicated bodies. But any attempt to explain the manner in which these changes take place would be exceedingly imperfect indeed; not only because we are ignorant of the strength of the affinities of the different elementary parts of animal bodies for each other, but because we do not even know the manner in which these elements are combined, and consequently we cannot know by what particular forces these compounds are destroyed.

Putrefaction under ground.

In carcases buried in the earth, putrefaction takes place much more slowly; but it is scarcely possible to observe its progress with accuracy. The abdomen is gradually dilated with elastic fluids, which make their appearance in it, and at last it bursts and discharges a horribly fetid and noxious gas; at the same time a dark coloured liquid flows out. If the earth be very dry, and the heat considerable, the moisture is often absorbed so rapidly, that the carcase, instead of putrefying, dries, and is transformed into what is called a *mummy*.

Such are the phenomena when dead bodies are left

Putrefaction of accumulated animal matter.

to putrefy separately : but when great numbers of car cases are crowded together in one place, and are s abundant as to exclude the action of external air an other foreign agents, their decomposition is entirely th consequence of the reciprocal action of their ingredient themselves upon each other, and the result is very dif ferent. The body is not entirely dissipated or reduce to mould, but all the soft parts are found diminishe remarkably in size, and converted into a peculiar sapo *naceous matter*. This singular change was first accu rately observed in the year 1786.

Converted into a saponaceous matter.

The burial ground of the Innocents in Paris havin become noxious to those who lived in its neighbour hood, on account of the disagreeable and hurtful odou which it exhaled, it was found necessary to remove th carcases to another place. It had been usual to di very large pits in that burial ground, and to fill the with the carcases of the poorer sort of people, each i its proper bier ; and when they were quite full, t cover them with about a foot deep of earth, and to di another similar pit, and fill it in the same manne Each pit held between 1000 and 1500 dead bodies. I was in removing the bodies from these pits that th saponaceous substance was found. The grave-digger had ascertained, by long experience, that about thirty years were required before all the bodies had undergon this change in its full extent *. Every part of the body acquired the properties of this substance. The intes tines and viscera of the thorax had completely disap peared ; but what is singular enough, the brain had los

* Fourcroy, *Ann. de Chim.* v. 154.

but little of its size or appearance, though it was also converted into the same substance. Chap. IV.

This saponaceous matter was of a white colour, soft and unctuous to the touch, and melted, when heated, like tallow. It exhibited all the properties of a *soap*, containing, however, an excess of fatty matter. Fourcroy, who analysed it, found that it was composed of a fatty matter combined with ammonia, and that it contained also some phosphate of lime and ammonia. Diluted acids decomposed it, and separated the fatty matter: alkalies and lime, on the other hand, drove off the ammonia. When exposed to the air it gradually lost its white colour; the ammonia, in a great measure, evaporated; and what remained had something of the appearance of wax. It absorbed water with great avidity, and did not part with it readily. Its white colour was owing to the presence of that liquid. The oily matter, when separated by means of a diluted acid, was concrete, and of a white colour, owing to the mixture of a quantity of water. When dried, it acquires a greyish-brown colour, a lamellar and crystalline texture, like that of spermaceti; but if it has been rapidly dried, it assumes the appearance of wax. It melts when heated to 126°; when properly purified, by passing it through a linen cloth while fluid, it has scarcely any smell. Alcohol does not act upon it while cold, but at the temperature of 120° it dissolves it: when the solution cools, the fatty matter precipitates, and forms a gritty mass. With alkalies it forms a soap; and when set on fire it burns precisely like oil or fat, only that it exhales a more unpleasant odour *.

Its properties.

* Fourcroy, *Ann. de Chim.* viii. 17. A set of experiments on a simi-

water, or preventing that liquid from acting upon these bodies in its usual manner. In this way the acids, sugar, alcohol, &c. seem to prevent or retard putrefaction. Chap. IV.

3. It is well known that common salt is a powerful antiseptic. Hence the practice of salting meat, and the length of time which meat that has undergone this operation may be kept. Several other salts, especially nitre, possess the same property. In what manner these bodies act has not been ascertained; but they undoubtedly produce some chemical change upon the meat; for they alter its taste, its colour, and other sensible properties.

4. Many aromatics, such as camphor, resins, volatile oils, bitumens, and other similar bodies, act with considerable efficacy in preserving animal bodies from putrefaction. Hence their utility in embalming. In what the action of these substances consists has not been ascertained. Part of their efficacy is doubtless owing to the rapidity with which the animal substances to which they are applied lose their moisture; and something may be ascribed likewise to their odour, which keeps insects at a distance, and thus prevents the lodging of excrementitious matter, which always acts powerfully as a putrefactive ferment.

APPENDIX.

In a science of so extensive a nature as Chemistry, which is cultivated in so many different countries, and by so numerous a body of eminent philosophers, new facts must be continually expected; and our opinions and theories, which serve merely as stepping-stones to conduct us to truth, must, in consequence, be frequently altered and modified anew. Since the commencement of this Edition a considerable time has elapsed, during which many important additions have been made to our knowledge. Such of these discoveries as could be introduced into the preceding Work have been already explained; those which were not published soon enough to be inserted in their proper place, or which did not come soon enough to hand, I think it necessary to enumerate in an Appendix, that the reader may have as complete a view as possible of the present state of the science. In this enumeration I shall follow exactly the order of arrangement which has been adopted in the Work itself.

Book I.
Division I.

PART I.—BOOK I.—DIVISION I.

CHAP. II. OF SIMPLE COMBUSTIBLES, Vol. I. p. 33.

SINCE this Chapter was printed several important experiments have been made on the simple combustibles, and a new one has been discovered and added to the list.

I. Carbon.

MR DAVY has exposed plumbago, well burnt charcoal, and the diamond, to the action of a galvanic battery in a Torricellian vacuum. Plumbago yielded no gaseous product whatever, neither was any change produced upon it when heated with potassium, excepting that it appeared to combine with that metal. Charcoal, in the Torricellian vacuum, gave out an intense purple light, and emitted some inflammable gas, 100 measures of which absorbed 75 measures of oxygen gas, and produced 37·5 measures of carbonic acid. These proportions correspond with those of no known gas. Potassium and charcoal when heated together combine, but evolve no gas. When the diamond and potassium are heated together in glass tubes, no elastic fluid is given out, but the diamond soon blackens, and scales seem to detach themselves from it. The potassium when thrown into water evolves less hydrogen, indicating that it has absorbed a portion of oxygen. From these experiments Mr Davy infers, that plumbago consists of pure carbon combined with about $\frac{1}{10}$th of iron, that charcoal contains a little hydrogen, and that the diamond contains a

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little oxygen *. But it appears, from the experiments of Thenard and Gay Lussac, that plumbago likewise contains hydrogen. For when oxymuriatic acid gas is passed over red-hot plumbago, it is converted partly into common muriatic acid gas. Now water is an essential constituent of that gas; of course water must have been formed, and the hydrogen must have been supplied by the plumbago. By a similar experiment these gentlemen ascertained the existence of hydrogen in charcoal †. Pure carbon then, unless hydrogen be admitted as a constituent of it, still continues unknown.

Brugnatelli has endeavoured to show that charcoal has the property of combining with oxygen, and with hydrogen, without altering its appearance much, and that the new compounds possess different chemical properties from pure charcoal ‡.

Azote from charcoal.

Berthollet has lately exposed charcoal to a violent heat in porcelain and glass retorts, and shown that the gas, which comes over, contains a mixture of azote. The proportion of this gas increases as the distillation proceeds. Hence he concludes that azote is one of the constituents of charcoal §. When the heavy inflammable airs obtained from charcoal, and from various animal and vegetable bodies, are detonated with oxygen, there is always a gaseous residue to be observed, which will not burn, and which is not absorbed nor altered by any substance applied to it or mixed with it. This residue is what Berthollet considers as azote. It is recognised merely by its negative properties, which seem

* *Phil. Trans.* 1809.

† *Mem. d'Arcueil*, ii. 344.

‡ *Ann. de Chim.* lxiv. 311.

§ *Mem. d'Arcueil*, ii. 484.

pit-coal frequently contains small quantities of sulphureted hydrogen, carbonic acid, and olefiant gas, and he has supposed that pure hydrogen gas is often an ingredient in the lightest gases. But this last supposition I consider as very unlikely to be true; for hydrogen has such a tendency to combine with carbon, that it can scarcely be evolved pure when in contact with charcoal. As to Berthollet's second opinion, that the heavy inflammable airs are all oxycarbureted hydrogen, I must acknowledge that every one of them examined by myself, and I have analysed a good many, contained oxygen. But this is not sufficient to decide the question; because, if carbonic oxide contains no hydrogen, and Berthollet himself allows that it sometimes is nearly free from it, we have only to suppose a mixture of that gas, to account for the oxygen which we find in the gases examined. Upon the whole, the subject is still so obscure, that many new experiments are necessary before our opinions can be fixed *.

II. Phosphorus.

From Mr Davy's experiments there is reason to conclude, that phosphorus contains both hydrogen and oxygen. When phosphorus is exposed to the action of a powerful galvanic battery, a quantity of phosphureted hydrogen gas is emitted, sometimes amounting to four times the bulk of the phosphorus acted upon. When phosphorus and potassium are fused together, they combine with a most vived light and intense ignition.

* *Mem. d'Arcueil*, ii. 68.

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phosphureted hydrogen
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II

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Chap. II.

diluted muriatic acid, sulphureted hydrogen gas is emitted, but less in quantity than the bulk of the hydrogen gas which the potassium would have given out when treated with water, and the quantity of sulphureted hydrogen gas is diminished by increasing that of the sulphur. Now this cannot well be explained, without supposing that the sulphur has given out oxygen to the potassium. Mr Davy has shown, that the sulphur in sulphureted hydrogen gas is in its usual state; yet when potassium is heated in this gas, it burns and is partly converted into potash; hence it must have absorbed oxygen from the gas, and hence the sulphur in that gas seems to contain oxygen *.

IV. Boracium.

This substance, which constitutes the base of boracic acid, has been recently separated and examined, in consequence of the new analytical methods pointed out by Mr Davy. Soon after his discovery of the method of decomposing the fixed alkalies, he exposed boracic acid to the action of the galvanic battery, and observed that a black matter was deposited upon the negative wire, which he considered as the basis of boracic acid. But he did not prosecute the discovery at the time. In the summer of 1808, Messrs Gay Lussac and Thenard succeeded in decomposing boracic acid, by heating it in a copper tube along with potassium. They examined its base, and published an account of its pro-

Analysis of boracic acid.

* *Phil. Trans.* 1809.

2. When heated in the open air, or in contact with oxygen gas, it takes fire at a temperature below the boiling point of olive oil, and burns with a red light and scintillations like charcoal, and is converted into boracic acid. It is difficult to burn it completely, because the boracic acid first formed, furnishes a vitreous crust, which protects the residue of the boracium from the action of the oxygen. When this crust is washed off, the boracium is found in the state of a black matter, which does not take fire till it be heated nearly to redness, and which absorbs less oxygen during its combustion than the olive coloured matter. Hence it is probable, that this black matter is an oxide of boracium.

Composition of boracic acid.

Gay Lussac and Thenard have concluded from their experiments, that 100 parts of boracium, when burnt, combine with 50 parts of oxygen, and form 150 of boracic acid. Mr Davy, on the other hand, has concluded from his experiments, that boracic acid is composed of 100 parts of boracium, and 200 of oxygen; and the black oxide of boracium, of 100 boracium, and 33 of oxygen. I have not had an opportunity of seeing the way in which the French chemists performed their experiments, as no details are given, either in the *Journal de Physique* (lxvii. 393), or in the Memoires d'Arcueil (ii. 311.), in both of which their account of boracium has been published. Mr Davy's experiments were made with great care; and though absolute precision in a case of this nature is not to be expected, they may, without hesitation, be received as at least a pretty close approximation to it. He found that 30 grains of potassium decomposed such a quantity of boracic acid, as left 2·4 grains of boracium,

and heated to whiteness, it assumes the lustre of plumbago, and becomes a conductor of electricity. In this state it effervesces slightly with water. But if it be exposed to the air for a few minutes it becomes olive, loses its conducting power, and its property of effervescing with water. When intensely heated, mixed with a little potassium, and covered with iron filings, it combines with the iron, and forms a dark metallic mass, which conducts electrity, and effervesces slightly with water. Such are the experiments which have led Mr Davy to suppose boracium to contain oxygen, and to conjecture that the pure base is of a metallic nature. Chap. III.

CHAP. III. SIMPLE INCOMBUSTIBLES.—SECT. I. AZOTE.—Vol. I. p. 104.

FROM the recent experiments of Mr Davy there are strong reasons to conclude that azote is a compound; but as these experiments have not yet led to results perfectly satisfactory, I shall give a detail of them rather under the head of ammonia than in this place, because they consist in treating that alkaline gas with potassium.

II. Muriatic acid.

MANY experiments on this acid have been recently made by Davy *, Thenard and Gay Lussac †, and Berthollet ‡, which have brought to light some singular

* *Phil. Trans.* 1809.
† *Mem. d'Arcueil*, ii. 339.
‡ *Jour. de Phys.* lxiv. 215.

drogen gas is developed, as apppears when potassium is treated with water.

Acid cannot be obtained pure.

2. Various attempts were made, both by Davy and the French chemists, to obtain muriatic acid gas free from water, by decomposing a muriate by means of some substance which contained no water. But none of these attempts were successful. When dry muriate of soda is mixed with vitreous boracic or phosphoric acids intensely heated, no decomposition whatever takes place; but if the vapour of water be brought in contact with the mixture, muriatic acid gas is disengaged abundantly. In the same way Mr Davy tried ineffectually to decompose common salt by means of dry sulphate of iron, though that salt in its ordinary state decomposes common salt very readily. When common salt and siliceous sand or dry clay are strongly heated, no decomposition takes place; but when the vapour of water comes in contact with these bodies, muriatic acid gas is disengaged in abundance. Corrosive sublimate is a salt which contains muriatic acid without any mixture of water. Attempts were made to obtain it from this salt by distillation with phosphorus; a liquid came over, which proved a compound of phosphorus and muriatic acid, and to which Thenard and Gay Lussac, the discoverers of it, have given the name of *phosphureted muriatic acid*. Mr Davy endeavoured to deprive this liquid of its phosphorus by means of potassium; but when the two substances were heated together, the consequence was a violent explosion, which destroyed the vessels. He succeeded indeed in depriving very minute quantities of this liquid of a considerable portion of their phosphorus, but the quantities were too small to determine exactly their properties. When the fuming

muriate of tin of Libavius is distilled with sulphur, there comes over a quantity of sulphureted muriatic acid, from which the muriatic acid cannot be separated free by any process hitherto tried.

Oxymuriatic acid

3. Oxymuriatic acid gas, as appears from the experiments both of Davy and the French chemists, contains no water as an essential constituent. It may be made perfectly dry by the usual hygrometrical methods. If it could be deprived of its oxygen, therefore, without losing its elasticity, muriatic acid gas would be obtained perfectly free from water.

Loses its elasticity when deprived of oxygen,

Experiments were made with that view both by Davy and the French chemists, but they were all unsuccessful. Mr Davy attempted to free oxymuriatic acid gas from its oxygen by means of phosphorus. The phosphorus, as is well known, burns spontaneously in this gas. During the combustion no muriatic acid gas was evolved. Two substances were obtained, a white sublimate which collected in the top of the retort, and a fluid as limpid as water, which trickled down its sides; the first was in considerable quantity, the last only in the quantity of a few drops. The sublimate emitted fumes of muriatic acid when exposed to the air. When brought in contact with water, it evolved muriatic acid gas, and left phosphoric acid and muriatic acid dissolved in the water. It was a non-conductor of electricity, and did not burn when heated, but sublimed completely at the temperature of 212°. It seems a compound of muriatic and phosphoric acids in their dry states. The fluid had a pale greenish yellow colour, and was very limpid. It disappeared rapidly in the open air, emitting dense fumes with a smell somewhat different from that of muriatic acid. It reddened litmus paper in its common

state, but had no effect upon paper which had been well dried. It was a non-conductor of electricity. t seems a compound of phosphorous and muriatic acids.

The action of sulphur to deprive oxymuriatic acid of its oxygen, was tried both by Davy and Thenard and Gay Lussac, but without success. No gas was evolved, but sulphureted muriatic acid was formed.

Unless water be formed.

When this gas is passed over well burnt charcoal heated to redness, a little muriatic acid gas comes over at first, but after a certain time the oxymuriatic acid gas passes through the red-hot charcoal without any change whatever. Hence it is obvious, that the decomposition, at first, is owing to the formation of water by the union of the hydrogen of the charcoal with the oxygen of the gas. Accordingly, the muriatic acid gas obtained contains its usual quantity of water. Hence it appears, that the action of oxymuriatic acid gas is the most powerful instrument known for depriving charcoal of the whole of the hydrogen which it contains.

Thenard and Gay Lussac have shown, that hydrogen gas, olefiant gas, and other similar gases, decompose oxymuriatic acid gas simply in consequence of the hydrogen which they contain, and which forms water by uniting with the oxygen of that acid gas. They have shown that gases which contain no hydrogen, as nitrous gas, produce no change upon oxymuriatic acid gas, unless water be present. As carbonic oxide is not decomposed by it, this is additional proof that hydrogen is not one of the constituents of that gas. Thus it appears that oxymuriatic acid is one of the most intimate combinations known, and that the presence of water, or the formation of it, is almost always necessary for its decomposition.

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Attempts to decompose muriatic acid.

4. As all attempts to procure muriatic acid gas free from water had failed, Mr Davy attempted to deprive the phosphureted muriatic acid, formed by distilling a mixture of phosphorus and corrosive sublimate, of its phosphorus. This he in some measure effected by distilling it repeatedly from potassium, which combined with the phosphorus. Ten or twelve drops of the liquor, that had been thus treated, were introduced into a small plate glass retort containing six grains of potassium. The retort was exhausted after having been twice filled with hydrogen gas. The liquid was made to boil, and the retort kept warm till the whole had disappeared as elastic vapour. The potassium was then heated by a spirit lamp. It scarcely had melted when it burst into a most splendid combustion, and the retort was destroyed. After many failures Mr Davy was enabled at last to obtain the results. No elastic fluid appeared to be evolved; a solid mass remained of a greenish colour at the surface, but dark grey within; it was extremely inflammable, and often burnt spontaneously when exposed to the air; when thrown upon water it produced a violent explosion, with a smell like that of phosphureted hydrogen. In the residue of its combustion were found muriate of potash, and phosphate of potash. This splendid combustion of potassium in the elastic fluid produced from phosphureted muriatic acid, is extremely singular, and cannot well be accounted for without supposing that the muriatic acid contributes to produce the effect. Were that admitted, it would follow that the muriatic acid had been decomposed by the process, and its oxygen absorbed by the potassium. But more satisfactory experiments will be requisite before so very important a consequence can be admitted.

5. From the experiments above detailed, there is reason to consider the muriatic as the most powerful of all the acids. It seems impossible to separate it from any of the bases, by other acids unless water be present. Chap. IV.

Chap. IV. Of Metals.—Vol. I. p. 131.

Several additions have been made to the chemical history of the metals since this Chapter was printed. Of these additions I shall now give a detail.

I. Iron.

I have committed a mistake in stating the quantity of oxygen in the oxides of this metal, which has lately been pointed out by Mr Hassenfratz *. The mistake was owing to the ambiguous method of expression used by Proust, the chemist on whose experiments I deduced the composition of these oxides. In consequence of Mr Hassenfratz's paper I have been induced to make a set of experiments on the subject, with as much care as possible to obtain exact results. The black oxide of iron I found composed of 100 parts of iron, and 27·5 of oxygen, or

Oxides of iron.

78·5	iron
21·5	oxygen
100·0	

* *Ann. de Chim.* lxx. 145.

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The red oxide I found composed of 100 iron and 45 oxygen, or nearly of 69 iron

31 oxygen

100

These results do not differ much from the proportions obtained by others. They destroy the conclusion which I have drawn, respecting an oxide of iron containing less oxygen than the black oxide. What I took for a new oxide was in all probability the black oxide itself. They render it necessary to alter the weight of an atom of iron, as deduced in the third volume, p. 538, from the mistaken ratio between the oxygen and metal contained in the oxides. We may conceive that there are three oxides of iron; the protoxide, still unknown, composed of 100 metal and 15 oxygen; the deutoxide, or black oxide, composed of 100 metal, $+2\times15$ oxygen; and the peroxide, or red oxide, composed of 100 metal $+3\times15$ oxygen. If the first oxide be supposed a compound of an atom of metal, and an atom of oxygen, it is obvious that an atom of iron will weigh 40, supposing an atom of oxygen to weigh 6.

I have examined Thenard's *white oxide of iron* with great care, but have always found abundance of sulphuric acid. When this acid is separated, the white colour always disappears, and it becomes green, black, and at last red.

II. Lead.

Descotils has published some experiments upon the action of the different gases on sulphuret of lead, which deserve attention, because they point out the

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sources of loss in the common methods of extracting lead from its ores.

When sulphuret of lead is exposed to a strong heat in a porcelain crucible, some sulphur is separated, a considerable portion of the sulphuret is sublimed, and there remains a subsulphuret of lead, which possesses ductility. When sulphurous acid gas and carbonic acid gas are passed through red-hot sulphuret, no change is produced, excepting that a portion of the sulphuret is sublimed, being carried off by the mechanical action of the gases. When steam is passed through sulphuret of lead, the sulphuret is sublimed in considerable quantity. The residue, besides sulphuret of lead, contains sulphate and lead in the metallic state. During the process hydrogen gas and sulphurous acid gas are disengaged. When hydrogen gas is passed through red-hot sulphuret of lead, some of the sulphuret is volatilized, but the greatest part is reduced to the state of metallic lead, and the hydrogen passes in the state of sulphureted hydrogen. When air is passed slowly over red-hot sulphuret of lead, almost the whole is converted into sulphate; but if it be passed rapidly, a white fume issues, having the smell of sulphurous acid, and depositing a fine white powder, which consists of sulphate of lead. Hence the great loss which is sustained when galena is treated in the open air, as is the case in all the operations usually practised in the reduction of lead ores. Descotils recommends iron as the best method of separating sulphur from galena. This metal is unfortunately too expensive for the purpose, but he recommends a trial of the rich ores of iron, pre-

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viously reduced to the metallic state by heating them to redness with charcoal *.

III. Nickel.

Some observations on nickel have been published by Professor Tourte of Berlin, made during the construction of a magnetic needle of nickel. It admits of a fine polish, and does not soon lose its lustre when exposed to the air. Its colour, when polished, is intermediate between that of platinum and steel. When heated to redness it becomes greenish grey. When its temperature is slowly raised, it undergoes a suite of changes of colour similar to polished steel. It becomes first light yellow, then deep yellow, light violet blue, deep violet blue, and last of all greyish blue. The colours have not the same intensity as those of steel. Tourte found the specific gravity of pure nickel, at the temperature of 55°, to be 8·402; but by strong hammering it was reduced to 8·932. He affirms that nickel wire burns like iron wire in oxygen gas; but when Gehlen repeated the experiment it did not succeed. Nickel may be drawn out into fine wire, but it is difficult to solder it, probably because its surface is apt to oxidize. It yields to the file, but soon destroys the file. It is a better conductor of heat than zinc or iron. The addition of a little arsenic does not destroy its magnetic properties. It is very easily converted into a magnet, and retains its magnetic virtue. The inclination of a

* *Mem. d'Arcueil*, ii. 424.

magnetic needle of nickel is the same as that of one of steel *. Chap. IV.

IV. Vestium.

It has been announced on the continent that a German chemist has discovered, in crude platina, a new metal, to which the name of *vestium* has been given †. No particulars respecting this discovery have yet reached this country. We do not even know whether the report be well founded.

V. Supposed New Metal in Manganese.

Dr John of Berlin announced the discovery of a new volatile and acidifiable metal in the grey ore of manganese from Saxony. He obtained it by distilling the ore with sulphuric acid. The volatile metallic acid combines with a weak solution of potash put into the receiver, and tinges it crimson. The infusion of galls throws down a chesnut brown precipitate from this liquor. The prussiates change the red colour to a fine lemon yellow, but produce no precipitate. When the liquor is heated with a little alcohol, it becomes green, and the alkaline carbonates throw down from it a brown coloured oxide; but they do not precipitate the liquid till it has been thus altered by alcohol ‡. Berzelius informs us that he was acquainted with this supposed new metallic substance as early as 1800, and

* *Ann. de Chim.* lxxi. 103.

† *Jour. de Phys.* lxvii. 71.

‡ Nicholson's *Jour.* xxiii. 159.

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He has shown that it depends upon the softness of the metal, which makes it escape from pressure. He found that when it was confined in such a manner that it could not make its escape, its specific gravity increased like that of other ductile metals. A piece of lead, thus treated, increased in specific gravity from 11·358 to 11·388.

VII. Oxidizement of Metals.

MORVEAU has published an experiment, showing that gold may be oxidized by electricity, in an imperfect vacuum of an air-pump; but that when the vacuum is complete, no oxidizement takes place. This is very likely; and it destroys the supposed anomaly of the oxidizement of metals in vacuo by electricity *.

Gay Lussac, in a paper published in the second volume of the *Memoires d'Arcueil* †, has endeavoured to prove, that the quantity of acid which combines with a metallic oxide, is always proportional to the quantity of oxygen which it contains. The protoxide of mercury consists of 100 metal united to 5 oxygen, the peroxide of 100 metal united to 10 oxygen; of course, according to this theory, the peroxide requires twice as much acid to saturate it as the protoxide. There can be little doubt that Gay Lussac was led to the notion of this law from the *atomic theory* of Dalton, which I have explained at great length under the article *affinity*, in the third volume of this work. He

* *Ann. de Chim.* lxix. 261.

† P. 159.

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has drawn his conclusions from the well known phenomena which take place when one metal precipitates another. When zinc is used to precipitate lead from the acetate, the acetate of zinc formed is just as neutral as the acetate of lead was. Suppose 100 grains of lead in the salt. The oxygen in such a quantity of lead may be rated at 8 grains. But 100 grains of zinc require 25 of oxygen to convert them into white oxide. Hence it is obvious, that the whole oxygen in the lead will only oxidize 32 grains of zinc. But as the acid is neutralized, it follows that 32 grains of zinc, combined with 8 of oxygen, are capable of neutralizing as much acetic acid, as 100 grains of lead combined with 8 of oxygen. Various other examples are brought by Mr Gay Lussac, all of a similar nature. If this law hold universally, as is extremely likely, though it would require a much more complete induction of particulars to prove it in a satisfactory manner, it will be of great importance, by enabling us to determine the composition of metallic salts, from the knowledge of the quantity of oxygen with which a metal combines, and the exact analysis of a single salt in each genus. Or, knowing the composition of the salts, it will enable us to determine the proportion of oxygen with which the different metals unite.

VIII. Metallic Hydrogurets.

It is probable that hydrogen gas is capable of dissolving a considerable number of the metals. Arsenical hydrogen gas is almost the only one of these combinations at present known. But Mr Davy has lately discovered two new ones, *tellureted* and *potassureted*

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hydrogen, consisting, as their names import, of hydrogen gas, holding in solution tellurium and potassium. He has also discovered *boruretted hydrogen*, a gas consisting of hydrogen holding boracium in solution. All of these gases contain their own bulk of hydrogen gas. Tellureted hydrogen is a weak acid, similar to sulphureted hydrogen.

IX. Metallic Phosphurets.

Grotthus has shown, that a solution of phosphorus in alcohol precipitates gold, silver, mercury, and copper, from their solutions in the state of phosphurets. If two parts of phosphorus, and one part of potash and soda, be heated in six parts of alcohol, a liquid is formed, which precipitates nitrate of lead orange, and muriate of antimony brown. These precipitates consist of phosphureted oxide of lead, and phosphureted oxide of antimony. During the heating of the phosphorus and alkali in the alcohol, a gas comes over which is inflammable, and which is a compound of phosphorus, carbon, and hydrogen. 100 measures of it require for combustion 72 measures of oxygen gas; the products are water, phosphoric acid, and carbonic acid *.

X. Tantalum and Columbium.

I omitted the account of *tantalum* (the metal discovered by Ekeberg), because it was announced by the discoverer of it, that he had ascertained it to be a com-

* *Ann. de Chim.* lxiv. 19.

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pound of known substances. This is probably incorrect. But Dr Wollaston has lately shown, by a very ingenious set of experiments, that it is the same with *columbium*, the metal previously discovered by Mr Hatchett. Columbite and tantalite, the ores from which the respective metals were obtained, were found composed of the same constituents, a white oxide, iron, and manganese. The white oxide from both possessed the same properties. It is nearly insoluble in sulphuric, nitric, and muriatic acids; but is easily dissolved by oxalic, tartaric, and citric acids, provided it be acted upon before it is dry. It is rendered soluble in water, by fusing it with potash or its carbonate. Soda may be employed, but a much greater quantity of it is necessary. Neither prussiate of potash, nor hydrosulphuret of potash, occasion any precipitate in solutions of this white powder; but it is thrown down orange by the infusions of galls, provided there be no excess either of acid or alkali present *.

Book I.—Division II.—Chap. II. Of Caloric.—Sect. III. Percussion. Vol. I. p. 611.

Berthollet, Pictet, and Biot, have lately made a set of experiments, to ascertain the quantity of heat evolved when ductile metals are suddenly struck forcibly, as when they are stamped in the process of coining. The experiments were made upon pieces of gold, silver, and copper, of the same size and shape,

* Nicholson's *Jour.* xxv. 23.

and care was taken that all the parts of the apparatus had acquired the same temperature before the experiments began. Copper evolved most heat, silver was next in order, and gold evolved the least. The first blow evolved the most heat, and it diminished gradually, and after the third blow was hardly perceptible. The heat acquired was estimated by throwing the piece of metal struck into a quantity of water, and ascertaining the change of temperature which the water underwent. The following table exhibits the increase of temperature, experienced by two pieces of copper by three successive blows;

1st Blow	1st Piece	17·44°
	2d Piece	20·80
2d Blow	1st Piece	7·30
	2d Piece	3·69
3d Blow	1st Piece	1·90
	2d Piece	1·46

The whole quantity of heat evolved by each of these pieces of copper is nearly the same; that from the first piece being 26·64°, and that from the second 25·95°.

The following table exhibits the heat evolved from two pieces of silver treated in the same way.

1st Blow	1st Piece	6·19°
	2d Piece	7·30
2d Blow	1st Piece	5·85
	2d Piece	2·14
3d Blow	1st Piece	2·76
	2d Piece	2·02
Total evolved from the 1st piece		14·74
Ditto from the 2d		11·46

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The change in specific gravity which the metals underwent, was found to be proportional to the heat thus evolved, as appears from the following table, deduced from their experiments. The specific gravities were taken at the temperature of 46·5°.

Specific gravity of gold	19·2357
Ditto annealed	19·2240
Ditto struck	19·2487
Specific gravity of silver	10·4667
Ditto annealed	10·4465
Ditto struck	10·4838
Specific gravity of copper	8·8529
Ditto struck	8·9893
Ditto struck a second time	8·9081

From these experiments it is obvious, that the heat evolved when metals are struck is owing to the condensation, and proportional to the condensation. Hence, when they can no longer be condensed, they cease to evolve heat. These philosophers observed, during their experiments, that heat or cold is propagated much more rapidly, from one piece of metal to another, when they are struck, than when they are simply placed in contact*.

Book II.—Division I.—Chap. I. Ammonia.
Vol. II. p. 5.

A great many experiments have been lately made on ammonia, some of them of a very extraordinary

* *Mem. d'Arcueil*, ii. p. 441.

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rè, and still very obscure; but they are highly deser- of attention, as they promise, when followed out tle farther, to throw a new and unexpected light the constituents of bodies, and some of the most plicated natural phenomena.

No less than four new analyses of ammoniacal have been made, in consequence of the experiments Davy, to show that oxygen is one of its constitu- : The first by Berthollet junior, the second by Lussac, the third by Mr Davy, and the fourth by Henry. Mr Davy had suspected the presence of gen as one of the constituents of ammoniacal gas, had made some experiments which appeared to ler his suspicions probable. These experiments I e related under the article ammonia. The object of new analysis was to determine how far this opinion Davy was correct.

Berthollet's analysis.

The experiments of Mr Berthollet junior were made every possible precaution to ensure precision. He ld detect the presence of no oxygen; nor was there notable quantity of water formed when great quan- s of the ammoniacal gas were decomposed by a red . When 1 of the gas is decomposed by electricity, bulk is increased to 2·04643. This expanded gas found composed, by bulk, of 155 parts of hydrogen, 245 of azotic gas, equivalent to 300 of hydrogen, 97·35 of azote. Converting these measures into ghts, according to the specific gravity of the different s found by Biot and Arrago*, Mr Berthollet has

* They found the specific gravity of azotic gas 0·96913; that of hy- n 0·07321; that of ammoniacal 0·59669; that of air being 1·000.

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concluded, from his experiments, that ammonia contains no oxygen, and that it is composed, by weight, of

81·13	azote
18·87	hydrogen
100·00 *	

The result of the experiments of Gay Lussac (if indeed his result is not drawn rather from theory) is, that ammonia is composed of 75 parts, by bulk, of hydrogen, and 25 of azote, or 300 hydrogen and 100 azote. Hence, from the specific gravity of the gases, as ascertained by Biot and Arrago, he deduces ammonia as composed, by weight, of

81·525	azote
18·475	hydrogen
100·000 †	

Henry's analysis.

Dr Henry found that the expansion of ammoniacal gas by electricity, was very much influenced by its state of dryness or moisture. When the gas had been dried by means of potash, when the mercury, over which it stood, had been recently boiled in the tube, and when every precaution was taken to exclude moisture, then 100 parts of the gas expanded by electricity to 180. But when these precautions were not taken, he found the bulk of the gas often doubled by electricity. This difference he explains in a satisfactory manner. If any moisture adhere to the mercury or tube, it absorbs a portion of the ammoniacal gas; this portion is evolved during the process, so that the real quantity of ammo-

* *Mem. d'Arcueil*, ii. 268. † Ibid. p. 253.

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niacal gas experimented on is greater than appears. No traces of the presence of oxygen, as a constituent of ammonia, could be perceived. The expanded gas he found a mixture of 74 measures of hydrogen gas and 26 of azotic. Now, if we take the specific gravity of azotic gas at 0·978, of hydrogen gas at 0·084, and of ammoniacal gas at 0·602; and suppose, as has been ascertained by the experiments of Sir George Shuckburgh, that at the temperature of 60°, and under the pressure of 30 inches of mercury, 100 cubic inches of common air weigh 30·5 grains; then we have 100 cubic inches of ammonia weighing 18·361 grains. These are expanded by electricity into 133·2 cubic inches of hydrogen gas, and 46·8 of azotic gas.

Now 133·2 inches of hydrogen weigh	3·413 grains
46·8 .... azotic	13·960
Weight of the gas evolved	17·373
Weight of the ammonia	18·361
	0·988

Thus it appears that the weight of the ammonia exceeds that of the gases nearly one grain, or about $\frac{1}{18}$th of the whole. This error, it must be acknowledged, is not great. But it is sufficient to show us that absolute precision has not yet been attained in estimating the proportion of the constituents of ammonia. The most probable source of error is in the specific gravity of the different gases. If we take the specific gravities of these different gases, as ascertained by Biot and Arrago, and given in a preceding note, the difference will amount to almost 1·4 grain. According to this analysis of Henry, ammonia is composed, by weight, of

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80·36 azote
19·64 hydrogen

100·00

Dr Henry has pointed out three other modes of analysing ammoniacal gas, all of which corroborate the preceding result.

Ammonia detonates with oxygen,

The first method is detonating a mixture of ammoniacal gas and oxygen gas by the electric spark. This method was tried by Berthollet junior, but he was not satisfied with the results *. Dr Henry has pointed out the sources of error, and shown how to avoid them. The mixture burns in all proportions between 3 oxygen and 1 ammonia, and 3 ammonia and 1·4 oxygen, by bulk. When the oxygen exceeds the ammonia (as when it is double or upwards), the whole ammonia disappears, and a quantity of nitrate of ammonia is deposited. This prevents the accuracy of the experiments by withdrawing a portion of the azote. When the ammonia exceeds (when it is double the oxygen, for example), the whole of the ammonia is decomposed by the explosion; part of its hydrogen unites with the oxygen, the rest remains mixed with the azote, and may be detonated by a second addition of oxygen. By this method the whole hydrogen may be separated, and its quantity determined. The residual gas (the oxygen being absorbed) gives the azote. It appears from Dr Henry's experiments, that 100 measures of dry ammoniacal gas, when thus treated, require, for complete saturation, 67·5 measures of oxygen. Hence it follows that the hydrogen, in 100 mea-

* *Mem. d'Arcueil*, ii. 284.

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sures of ammonia, is equivalent to 135 measures, which differs a little from the quantity deduced by the same philosopher from his electrical experiments.

Nitrous oxide,

The second method is to detonate a mixture of ammoniacal and nitrous oxide gases. This mixture burns in any proportion between 1 ammonia and 5 nitrous oxide, and 2 ammonia and 1 nitrous oxide. When the nitrous oxide greatly exceeds, there is no diminution of bulk after firing, and the residue consists of a mixture of nitrous oxide, oxygen, and azote. When the ammonia is redundant, there is a little diminution of bulk after firing, and the residue consists of a mixture of hydrogen and azote, with occasionally a little undecomposed ammonia. 100 measures of ammonia require, for saturation, 130 measures of nitrous gas.

And nitrous gas.

The third method is to detonate a mixture of ammonia and nitrous gas; for, although this gas cannot be fired with hydrogen or the heavy inflammable gases, it may with ammonia. 100 measures of ammonia require about 120 measures of nitrous gas *.

Composed of hydrogen and azote.

Mr Davy's late experiments coincide exactly with those of Dr Henry, and give as a result, that ammonia is composed of 74 measures, by bulk, of hydrogen gas, and 26 of azotic gas. It is not necessary therefore to enter into details.

By the experiments just related, it seems fully established that ammonia is composed simply of hydrogen and azote, and that oxygen does not enter as a constituent. On the other hand, it seems to follow, from the curious amalgam obtained from ammonia by the gal-

* Henry's Experiments on Ammon *Phil. Trans.* 1809.

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vanic energy, as related under the article *ammonia*, that oxygen is really a constituent of ammonia. This leads to the conclusion, that either hydrogen or azote is a compound, and that oxygen is one of its constituents.

The experiments of Berthollet junior, respecting the expansion of ammoniacal gas by electricity, do not agree with those of Davy and Henry. From the great precautions taken by the British chemists, we have reason to confide in the results which they obtained. As to the proportional measures of the two gases obtained, all the experimenters very nearly agree, as will appear from the following Table:

	Hydrogen.	Azote.
Berthollet	75·5	24·5
Davy	74·0	26·0
Henry	73·75	26.25
Mean	74·42	25·58

This differs but little from the proportions of Gay Lussac, namely 75 measures of hydrogen and 25 of azote; numbers which, on account of their proportions to each other, are exceedingly convenient. If we were accurately acquainted with the specific gravity of hydrogen and azote, it would be easy to determine the exact composition of ammonia with almost perfect accuracy.

Action of potassium on ammonia.

2. When potassium is heated in contact with dry ammoniacal gas, it is changed into an olive coloured matter; a great quantity of the ammoniacal gas is absorbed, and a quantity of hydrogen gas is evolved. According to Messrs Gay Lussac and Thenard, the hydrogen gas evolved amounts to about $\frac{2}{5}$ds of the bulk of the ammoniacal gas absorbed. When the olive coloured

matter is heated, about $\frac{3}{5}$ths of the ammonia absorbed is obtained; $\frac{2}{5}$ths in the state of ammonia, and $\frac{1}{5}$th in the elements of that compound. If a few drops of water be brought in contact with the olive coloured matter thus heated, the other $\frac{2}{5}$ths of the ammonia absorbed are disengaged, while at the same time the potassium is changed into potash. Thus, according to these chemists, the whole of the ammonia absorbed may be recovered. By the process the potassium is converted into potash and hydrogen. Hence they have concluded that potassium is not a simple substance, and the base of potash, but in reality a compound of potash and hydrogen *. Chap. I.

The experiments of Mr Davy on this subject, made with every precaution, and multiplied and varied in every possible way, do not agree with those of the French chemists, and destroy the consequences which they have drawn respecting the composition of potassium; but they lead to others, if possible, still more extraordinary.

Hydrogen emitted.

When ammonia is brought into contact with about twice its weight of potassium, at the temperature of the atmosphere, the metal loses its lustre and becomes white; there is a slight diminution in the volume of the gas, but no other effects are produced. The white crust formed is potash, and the ammonia is found mixed with a quantity of hydrogen, about equal to the bulk of the metal. On heating the potassium the colour of the crust changes from white to bright azure, and passes through shades of blue and green to dark olive. There is a considerable effervescence; the metal be-

* *Mem.* ii. 308.

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comes porous, and appears crystallized, and at last is wholly converted into an olive coloured matter. Ammoniacal gas is absorbed, and hydrogen gas evolved. The proportion of ammonia absorbed varies according to its state of dryness; the absorption being the greater the drier the gas is. Thus 8 grains of potassium, when heated in contact with ammonia saturated with moisture, absorbed $12\frac{1}{4}$ cubic inches of ammonia; but when the ammonia was as dry as possible, 16 cubic inches were absorbed. The hydrogen gas evolved depends upon the quantity of potassium. It is always a very little less than the quantity of hydrogen, which the same quantity of potassium would generate when brought in contact with water. Thus 8 grains of potassium, by their action on water, produced 8·5 cubic inches of hydrogen gas, while, by their action on ammonia, $8\frac{1}{8}$ cubic inches were evolved.

Olive coloured matter.

The olive coloured matter, into which the potassium is converted, possesses the following properties: It is crystallized, and presents irregular facets, which are very dark, and in colour and lustre not unlike protoxide of iron. It is opaque in large masses, but semitransparent in thin films, and appears brown by transmitted light. It melts at a little above the temperature of 212°; and if the heat be increased, gives out bubbles of gas. It is considerably heavier than water. It is a non-conductor of electricity. When melted in oxygen gas it burns with great brilliancy; oxygen is absorbed, azote emitted, and potash formed. When brought in contact with water it produces heat, and often inflammation, and evolves ammonia. When plunged into water it disappears with effervescence, and hydrogen gas is evolved. It rapidly effervesces and deli-

quesces in air, but may be preserved under naphtha, in which, however, it gradually softens, and seems partially to dissolve. Chap. I.

Potassium, when converted into this olive coloured matter, increases in weight; and it, together with the hydrogen evolved, is equal to the weight of the whole potassium employed, and of the ammonia absorbed.

Action of heat on it.

When the olive coloured substance is gradually heated it melts, effervesces, and gives off a considerable quantity of elastic fluid, and at last, in a red heat, is converted into a dull grey solid, which undergoes no farther alteration at that temperature. The olive coloured matter from 8 grains of potassium, by this process, gave out 13·75 cubic inches of gas. These consisted of

1·00	ammonia
9·11	hydrogen gas
3·64	azotic gas
13·75	

We may observe here, that more than one half of the ammonia has disappeared in this experiment. The quantity absorbed (deducting the cubic inch evolved) may be stated at 15 cubic inches, which weigh 2·754 grains. But the whole weight of the hydrogen and azotic gas evolved does not exceed 1·327 grain.

The quantity of ammonia evolved from the olive coloured substance depends upon the application of moisture; and it appears likely, from Mr Davy's experiments, that if moisture were applied only in the requisite proportion, the ammonia evolved would be just equal to what had been absorbed in the first part of the process. In one experiment, in which 13 cubic inches of ammonia had been absorbed, by heating the olive

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coloured substance, in contact with potash containing its water of crystallization, nearly 11·75 cubic inches of ammonia were evolved. It appears probable, likewise, that when no moisture whatever is present, no ammonia is given out.

The substance that remains, after the olive coloured matter has thus been exposed to a red heat, possesses the following properties. Its colour is black, and its lustre not much inferior to that of plumbago. It is opaque, very brittle, and gives a deep grey powder. It is a conductor of electricity. It does not melt at a low red heat, but blackens glass at that temperature, and a greyish sublimate rises from it, which likewise blackens glass. When exposed to the air, it burns spontaneously with a deep red light. With water it effervesces, evolving ammonia, and leaving nothing but potash. A little hydrogen is also evolved. It does not act on mercury, but combines with sulphur and phosphorus by heat; the compounds are highly inflammable, and emit ammonia, and phosphureted and sulphureted hydrogen gas, respectively, by the action of water.

A deficiency of azote.

This residuary matter ought to be a compound of potassium, azote, and a little oxygen. For most of the hydrogen in the ammonia has been evolved; 15 cubic inches of ammonia would have evolved about 20 cubic inches of hydrogen, and there were obtained above 17 inches. But little more than half the azote has been evolved; 15 cubic inches of ammonia ought to give out nearly 7 inches of azotic gas, whereas only 3·64 were obtained. When the residue was burnt in oxygen gas, potash was formed, and azotic gas given out; but the quantity was much smaller than it ought

to be. When the residue was violently heated in a tube of platinum or iron, one portion of it was converted into potash, another portion became pure potassium, and an elastic fluid was given out, consisting chiefly of hydrogen mixed with a little azote. Thus it appears, that, by these processes, a greater quantity of hydrogen, and a smaller quantity of azote was obtained, than ammonia yields when decomposed by electricity; while a portion of the potassium was converted into potash, and of course had combined with oxygen. The obvious inference from these experiments is, that a portion of the azote had been decomposed, and that its constituents are hydrogen and oxygen; the first separated in the form of gas, the last united with the potassium. But the subject requires a much more complete investigation, before consequences of so much importance can be deduced. Mr Davy is at present engaged in the investigation; and it is to be hoped, that his experiments will elucidate this most important, but very obscure department of chemistry.

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Chap. II. Fixed Alkalies. Vol. II. p. 22.

From the experiments of Mr D'Arcet, it appears, that potash or soda, prepared by means of alcohol, and exposed for some time to a red heat, still retain about 27 *per cent.* of water, which can only be separated by combining the alkali with an acid *. This corresponds nearly with the estimate of Curaudau, who found that

* *Ann. de Chim.* lxviii. 175.

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potash, prepared by means of alcohol, still retained 27·5 *per cent.* of water *. Berthollet had convinced himself, that at least 13 *per cent.* of water adhered to the alkali, and could not be separated by heat †.

New method of procuring potassium.

Curaudau has pointed out a new method of procuring potassium and sodium. It consists in mixing the alkaline subcarbonates with charcoal and a little oil, and gradually raising them to a white heat in iron tubes or earthen-ware retorts. The metallic substances are generated and volatilized. By exposing cold iron rods to the fumes, they condense, and may be separated by plunging the rod into naphtha or oil of turpentine. This method is of importance, by proving that charcoal is capable of decomposing the alkalies; but the quantity of metal that can be collected by this process must be small ‡.

Several additions have been made to our knowledge of the properties of potassium and sodium, by the experiments of Gay Lussac and Thenard; their results do not always agree with those of Mr Davy, though in general they do. Their potassium was obtained by decomposing potash, by means of iron turnings, in the experiment with the gun-barrel. It was heavier than Mr Davy's, being of the specific gravity 0·874, owing probably to its containing some iron: but, in other respects, its properties corresponded. It appears, from Mr Davy's experiments, that a grain of potassium, when brought in contact with water, gives out $1\frac{1}{16}$, = 1·0625, cubic inches of hydrogen gas, at the temperature of

Hydrogen evolved by potassium.

* *Jour. de Phys.* lxvii. 9.

† *Ann. de Chim.* lxviii. 181.

‡ Nicholson's *Jour.* xxiv. 37.

60°, and under a pressure of 30 inches of mercury. By the experiments of Thenard and Gay Lussac, the hydrogen given out by 1 grain of potassium, acting on water, under the same pressure and at the same temperature, amounts to 1·1591 cubic inch *.

Potassureted hydrogen.

According to the French chemists, potassium absorbs a great quantity of hydrogen gas, and assumes a greyish white colour. Abundance of hydrogen may be expelled by the action of heat. Mr Davy's account is different. He found that hydrogen has the property of dissolving a considerable quantity of potassium, and of forming a gas, to which he gives the name of potassureted hydrogen. It takes fire when it comes in contact with the air.

Action of potassium on salts.

Thenard and Gay Lussac tried the effect of potassium upon various metallic oxides and salts in a dry state. Their method was to put a piece of potassium, of the size of a pea, into a glass tube, and to cover it with about ten times the bulk of the substance to be tried. The tube was then exposed to a heat sufficient to melt the potassium. All the substances tried were decomposed, and in many cases combustion took place. The following is a summary of their experiments.

1. Sulphate of barytes. Decomposed, but without inflammation.
2. Sulphate of barytes. Brilliant inflammation.
3. Sulphate of lime. Slight inflammation.
4. Sulphate of lead. Brilliant inflammation.
5. Sulphate of mercury. Inflammation.

* *Mem. d'Arcueil*, ii. 302.

32. Grey oxide of nickel. Brilliant inflammation.
33. Green oxide of chromium. No inflammation. A black substance produced, which takes fire in the open air.
34. Sulphuric, nitric, and liquid muriatic acids. Splendid inflammation *.

Nature of potassium.

Messrs Thenard and Gay Lussac have endeavoured to prove, that potassium and sodium are not the bases of the fixed alkalies, but compounds of the fixed alkalies and hydrogen. This hypothesis has been very generally embraced both in France and Germany. It is not, however, consistent with the phenomena, and has been victoriously refuted by Mr Davy. The most plausible argument urged in defence of it is, the low specific gravity of potassium and sodium, considerably inferior to that of potash or soda. Now, no instance is known of a metallic oxide specifically heavier than the metal which constitutes its base. This objection is only apparent. What we call potash and soda, at present, are only the hydrates of these bodies. We are entirely ignorant of the specific gravity of the pure alkalies. Their union with water is intimate; of course, the condensation of the water is great. For any thing we know to the contrary, the hydrates may be much heavier than the pure alkalies.

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* *Mem. d'Arcueil*, ii. 334.

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Book II.—Division II.—Chap. II. Acids.
Vol. II. p. 169.

A variety of interesting additions to the history of the acids have been made. Of these I now proceed to give an account.

I. Fluoric Acid.

All attempts to procure fluoric acid in a state of complete purity have failed. In its usual state, when obtained by means of fluate of lime and sulphuric acid in glass vessels, it holds, as is well known, silica in solution.

Thenard and Gay Lussac endeavoured to procure it pure, by calcining in an iron tube a mixture of fluate of lime and vitreous boracic acid. An acid gas is procured in abundance. When mixed with air or any other gas, except the oxymuriatic acid, it produces dense white fumes, unless the gases have been previously artificially dried. Water absorbs this gas in great quantities, and when saturated with it is limpid, smoking, and very caustic. By heat, about one fifth part of the gas is expelled, but no degree of heat is capable of driving off more. The liquid then assumes the appearance of sulphuric acid; it is equally caustic, does not boil till heated considerably above the boiling point of water, and when distilled over, condenses like that acid. It acts like sulphuric acid on vegetable substances, charring them, and forming a quantity of water. With alcohol it forms a peculiar ether. This remarkable acid, which does not act on glass, is a combina-

Fluo-boric acid.

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tion of fluoric and boracic acids. Thenard and Gay Lussac have given it the name of *fluo-boric* gas*.

Liquid fluoric acid.

When fluate of lime and sulphuric acid are heated in leaden vessels, no gas is obtained, but only an acid liquid, consisting of water and fluoric acid combined together. When exposed to the air it emits vapours. When mixed with water it heats, and even enters into ebullition. When brought in contact with glass, it acts upon it, becomes hot, and is converted into siliciferous fluoric acid gas. When allowed to touch the skin, a white spot is formed, with the pain of a burn, which terminates in a blister. The best remedy is to touch the place with a weak solution of potash. When brought in contact with potassium, a violent combustion takes place, hydrogen is evolved, and fluate of potash and water disengaged†.

Action of potassium on fluoric acid.

When potassium is placed in contact with fluoric acid gas, holding silica in solution, white fumes appear, the metal loses its splendour, is covered with a white crust, and some hydrogen gas is evolved. When heat is applied, the metal bursts through the crust, becomes first of a copper colour, then bluish black, and at last inflames and burns with a most brilliant red light. The whole, or a part of the fluoric acid gas disappears, according to the portion of potassium present; a chocolate coloured mass remains in the bottom of the retort, and a sublimate, in some parts chocolate, in others yellow, is found round the sides and at the top of the retort. When the fluoric acid gas has been

* *Mem. d'Arcueil*, ii. 317.

† Ibid. ii. 323.

dried, the residual gas amounts to about $\frac{1}{13}$th of the fluoric acid gas destroyed; when the gas has not been dried, it amounts to about $\frac{1}{8}$th part. Hence, probably, it is owing to the decomposition of water, for it possesses the properties of hydrogen.

The chocolate coloured matter formed, when examined with the magnifier, appears to consist of different substances mixed together; a blackish matter, a white apparently saline matter, and a substance having different shades of brown and fawn. It is a non-conductor of electricity. When thrown into water, it effervesces strongly, and an inflammable gas is evolved, having some resemblance in smell to phosphureted hydrogen gas. When heated in the open air, it burns, and is converted into a white saline mass *. There can be little doubt that the fluoric acid gas is decomposed during this combustion, and that its basis exists in the chocolate coloured residuum; but, as it appears to form a compound with the potash formed, it has not been possible hitherto to ascertain its properties. In this respect fluoric acid resembles sulphuric and phosphoric acids, which are decomposed by potassium, but their bases combine with the potash formed.

II. Boracic Acid.

I HAVE given, in page 773 of this Appendix, an account of the composition of this acid, and of the properties of its basis, to which the name of *boracium*

* Davy, *Phil. Trans.* 1809.

has been given. It appears to be a compound of two parts oxygen, and one part of boracium. Chap. II.

III. Oxymuriatic Acid.

The recent experiments of Thenard and Gay Lussac, related in a preceding part of this Appendix, alter our notions respecting this acid. Instead of the oxygen being loosely combined, it appears to be united most firmly to the muriatic acid, and not to be capable of being separated, even by the action of carbon at a red heat. The easy decomposition of this acid, in common cases, is owing to the strong affinity of muriatic acid for water.

Majon has observed, that when bottles filled with oxymuriatic acid gas are exposed to the sun, the colour and smell disappears, and a smell is observed similar to that of muriatic ether. Hence he suspects that ether is formed during the decomposition of this acid by light. But his experiments are altogether insufficient to prove the truth of this opinion *.

IV. Chromic Acid and Chromates.

Vauquelin has recently published an important paper on the method of procuring chromic acid and oxide of chrome, and on the combination of these bodies with bases and acids †.

It is from chromate of iron that these substances are usually procured, because that is by far the most abun-

* [illegible] lxiv. 264. † *Ann. de Chim.* lxx. 70.

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dant ore of that metal. Two parts of this substance are mixed with one part of nitre, and calcined for some time in a crucible. The mass is digested in water, the liquid separated, and the residue treated with muriatic acid. The acid solution is speedily decanted off, and the residue, which is chromate of iron undecomposed, is to be calcined a second time with the fourth part of its weight of nitre, and treated as before. When the ore is completely decomposed, the aqueous solutions, which contain the oxide of chromium, are to be collected, saturated with nitric acid, and crystallized, in order to separate some impurities. The salt is then to be dissolved in water, and mixed with a solution of nitrate of mercury, containing as little excess of acid as possible. A red precipitate falls, consisting of the chromic acid combined with the mercury. It is to be thoroughly washed, and exposed to heat in a stone-ware retort. The oxide of chromium remains in a state of purity.

How to obtain chromic acid.

Chromic acid may be obtained pure by mixing chromate of potash with nitrate of barytes. The precipitate, which consists of chromate of barytes, is to be well washed, and exactly decomposed by means of sulphuric acid, not added in excess. The sulphate of barytes being separated, the liquid is to be cautiously evaporated to dryness, water added, and the process repeated two or three times, in order to get rid of the nitric acid.

Oxides of chromium.

The oxide of chromium is green, the chromic acid red. 100 parts of oxide of chromium are converted into chromic acid by combining with 16·6 parts of oxygen. Chromic acid is decomposed by sulphurous acid, and converted into oxide of chromium. The colour is

at first reddish brown, but by heat it is converted into green.

Oxide of chromium, obtained by calcining chromate of mercury, is soluble in acids with great difficulty; but the oxide of chromium, obtained by decomposing chromate of potash by sulphureted hydrogen, filtrating and adding a little potash, is easily soluble in the different acids.

Salts of chromium.

The sulphate of chromium is easily decomposed by heat. Muriate of chromium, evaporated to dryness, leaves a red powder, which deliquesces in the air. The solution is green. When heated oxymuriatic acid gas is given out, it swells up, and is converted into yellow plates, and at last nothing remains but green oxide. Nitric acid dissolves oxide of chromium with facility, and without altering its nature; but if the solution be evaporated to dryness, a portion of the oxide is converted into acid. Phosphate of chromium has an emerald green colour, oxalate of chromium is of an amethyst red. Sulphurous acid readily dissolves the oxide of chromium. Oxide of chromium, recently precipitated, is soluble in caustic potash; the solution has a fine green colour.

Chromate of potash.

Chromate of potash.—There are two varieties of this salt: 1. The neutral chromate, of a lemon yellow colour, which crystallizes in small prisms. When heated it becomes red, but assumes its natural colour on cooling. 2. The superchromate, which has an orange yellow colour, and crystallizes in fine prisms.

Chromate of ammonia.

Chromate of ammonia.—When chromic acid is saturated with ammonia, and the liquid set aside, a salt gradually forms of a fine yellow colour. It is decomposed by a slight heat, even when in solution, brown

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flocks of chromic acid precipitating, which become green when calcined.

Chromate of barytes.

Chromate of barytes.—This salt is easily formed by mixing chromate of potash and nitrate of barytes. The salt precipitates in powder. It is not sensibly soluble in water, and is composed of

40·16 chromic acid
59·84 barytes

100·00

Chromate of lime.

Chromate of lime.—This salt is pretty soluble in water. By evaporation it yields silky plates of a yellowish brown colour, readily soluble in water. The fixed alkalies decompose it.

Chromate of magnesia.

Chromate of magnesia.—This salt is very soluble in water. It crystallizes in transparent six-sided prisms, of a fine topaz yellow colour. When in large masses its colour is orange yellow. The magnesia is precipitated by the caustic fixed alkalies, and the alkaline earths.

Chromate of iron.

Chromate of iron.—When chromate of potash is dropt into sulphate of iron, a fawn coloured precipitate falls, which contains oxide of chromium. Hence it appears that the black oxide of iron decomposes chromic acid. To compose chromate of iron, then, we must employ oxysulphate of iron.

Chromate of lead.

Chromate of lead.—This salt assumes different shades of colour according to the method of preparing it. Neutral chromate of potash throws it down of an orange yellow, superchromate of a deep lemon yellow, subchromate of a yellowish red or deep red. The chromate of lead, made by means of a solution slightly acid,

has the colour which is most sought after by painters, and which in reality is the most solid. Chap. II.

Chromate of copper.—This salt may be formed by mixing together solutions of chromate of potash and sulphate of copper. A precipitate falls, which is at first yellowish brown, but becomes bistre brown when dried.

Chromate of silver.—This salt may be formed by mixing chromate of potash and nitrate of silver. The precipitate is reddish brown when the liquids are mixed hot, purple red when they are mixed cold, and carmine red when the chromate of potash contains an excess of acid. It becomes brown when exposed to the light, and is soluble in nitric acid.

Oxide of chromium is employed to colour porcelain. It gives a fine green, and resists a strong heat, better than most other metallic colours. An enamel is made of it, which, when applied to copper or silver, imitates very exactly the colour of gold *.

V. Acetic Acid.

From recent experiments, as well as others made long ago, it appears that the specific gravity of acetic acid does not indicate its strength. Thus Mollerat found two specimens of acid of the same specific gravity, namely 1·0630; though the first contained 0·87125 of acid, and the other only 0·41275. When water is added to the strongest acid, its specific gravity increases till it amounts to 1·0791. The acid then contains 0·67256 of its weight of acid. If more water be added, Specific gravity.

* *Ann. de Chim.* lxx. 70.

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the specific gravity gradually diminishes. Thus it appears that the specific gravity of acetic acid increases with its strength till it reaches 1·0791, when the proportion of acid amounts to 0·67256. The specific gravity after this diminishes as the strength increases *.

These changes in the specific gravity are sometimes occasioned by the presence of a peculiar spiritous liquor in strong acetic acid. This liquor being lighter than water, balances the specific gravity of the acid, and thus causes the mixture to be specifically lighter, even when the quantity of acid is increased. We are indebted to Mr Chenevix for an important set of experiments on the formation and properties of this peculiar spiritous liquor, to which he has given the name of *pyro-acetic spirit* †. The following is a summary of the most important parts of these experiments.

English vinegar, of the specific gravity 1·0042, was found to contain, besides water and acetic acid, a peculiar vegetable matter, which may be distilled over with the liquid, and which has been sometimes called *mucilage*, sometimes *extractive*. It contains also traces of a spiritous liquor. French vinegar was found to contain the same substances, but their proportion was different. Its specific gravity was 1·0072, and it contained more acetic acid and spiritous liquor, and less mucilage, than English vinegar.

Distillation of metalline acetates.

When the metalline and alkaline or earthy acetates are distilled, acetic acid, mixed with water, and this pyro-acetic spirit, is obtained. The metallic base, mixed with charcoal, remains in the retort; and there flies off

* Mollerat, *Ann. de Chim.* lxviii. 88.

† Ibid. lxix. 5.

a mixture of carbonic acid and heavy inflammable gas. The metallic base is usually reduced to the metallic state; and the more difficult this reduction is, the greater is the quantity of pyro-acetic spirit formed. The following Table exhibits the result of the distillation of seven metalline acetates in a state of purity. Chap. II.

		Acetate of Silver.	Acetate of Nickel.	Acetate of Copper.	Acetate of Lead.	Acetate of Iron.	Acetate of Zinc.	Acetate of Manganese.
	Loss by the fire,	0·36	0·61	0·64	0·37	0·49		0·555
Residue in retort.	State of base.	Reduced.	Reduced.	Reduced.	Reduced.	Black oxide.	White oxide.	Black oxide.
	Charcoal.	0.05	0·14	0·055	0·04	0·02	0·05	0·035
Liquid products.	Sp. Gravity.	1·0656	1·0398	1·0556	0·9407	1·011	0·8452	0·8266
	Propor. of acid.	107·309	44·731	84·868	3·045	27·236	2·258	1·285
	Spiritous liquor.	0	0·2	0·17	0·555	0·24	0·695	0·94
Gaseous products.	Carbonic acid.	8	35	10	20	18	16	20
	Carb. hydrogen.	12	60	34	8	34	28	32
	Total of gas.	20	95	44	28	52	44	52

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The acetates of potash and of soda give a greater proportion of pyro-acetic spirit than any of the metallic acetates. When acetate of barytes is distilled, the whole liquid product consists of this spirit without any mixture of acid whatever.

Pyro-acetic spirit.

This pyro-acetic spirit is quite the same in its properties, from whatever acetate it is procured. No other genus of salts tried, as the oxalates, tartrates, citrates, yield this spirit. Acetic acid is not converted into it by heat. Mr Chenevix distilled the same proportion of acetic acid five or six times through a red-hot porcelain tube; part of it was decomposed, the liquor became brown, and its specific gravity was diminished, but a considerable proportion remained unaltered. But if charcoal be put into the porcelain tube, the acid is destroyed by one distillation, and nothing obtained but water, carbonic acid, and heavy inflammable air.

Its properties.

Pyro-acetic spirit is a white and limpid liquid. Its taste is at first acrid and hot, but it becomes cooling, and in some sort urinous. Its smell is peculiar, and is compared by Mr Chenevix to that of a mixture of oil of peppermint and bitter almonds. Its specific gravity, when as pure as possible, is 0·7864. It burns with a flame, white exteriorly, but of a fine blue within, and leaves no residue. It boils at the temperature of 165°. It mixes with water, alcohol, and volatile oils in any proportion. With hot olive oil also it mixes in any proportion; but with that oil cold it mixes only in certain proportions. It dissolves a little sulphur and phosphorus, and is an excellent solvent of camphor. When hot it dissolves wax and tallow. A portion of these substances precipitates as the solution cools, but water still occasions a considerable precipitate in it. It dissolves potash, and becomes darker coloured; but it may

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be obtained by distillation again unaltered. When mixed with sulphuric acid it blackens and is decomposed, and much charcoal is formed. When mixed with nitric acid it becomes yellow, and its properties are altered. Some oxalic acid is formed. Muriatic acid renders it brown. When distilled with this acid a combination takes place, and a substance is formed, possessing very different properties from muriatic ether. Thus it appears that pyro-acetic spirit is a liquid possessing properties peculiar to itself, and quite different from those, both of alcohol, ethers, and volatile oils. It deserves, of course, a peculiar place among compound combustibles.

VI. Benzoic Acid.

Fourcroy and Vauquelin some time ago announced, that benzoic acid might be obtained from the urine of herbivorous animals. Advantage has been taken of this discovery, and a benzoic acid, obtained from the urine of cattle, introduced into commerce in France. It has the colour and lightness of common benzoic acid, but it wants its aromatic smell. Fourcroy and Vauquelin have ascertained, that if it be mixed with about $\frac{1}{6}$th of its weight of benzoin in powder, and sublimed a second time, it acquires the smell and all the other properties of common benzoic acid *.

VII. Saclactic acid.

Trommsdorf has lately subjected this acid to distil-

* Ann. de Chim. lxix. 311.

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lation, and examined the products. During the process the acid swells, blackens, and melts; a liquid passes into the receiver, at first colourless, then yellow, accompanied with heavy white vapours, and followed by a little empyreumatic oil; carbonic acid gas is disengaged, mixed with a little heavy inflammable gas. At the end of the process a brown transparent liquid is found in the receiver, mixed with a number of crystals. A quantity of charcoal remains in the retort, which has the metallic lustre, and which, when incinerated, leaves traces of lime. The liquid in the receiver contains acetic and pyrotartaric acids, but no traces of prussic acid or ammonia. The crystals possess the properties of succinic acid *.

VIII. Suberic Acid.

CHEVREUL has lately subjected suberic acid to a new examination, and has added considerably to our knowledge of its properties. He obtained it by digesting 1 part of cork in 6 parts of acid. After the acid had ceased to act, the whole was evaporated to the consistence of an extract, hot water was poured over, and the mixture was digested for some time in a sand heat. When set aside, a matter like wax formed on the surface, and white tasteless flocks precipitated to the bottom. These substances were separated, and the liquid concentrated by evaporation. Suberic acid precipitated in powder, and towards the end of the process crystals of oxalic acid formed. I observed the formation of

* Ann. de Chim. lxxi. 79.

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oxalic acid some years ago, while treating cork with nitric acid.

Suberic acid thus formed may be purified by washing it in cold water. It is then white like starch, and has an acid taste without any bitterness. Light does not alter its whiteness. Water, at the temperature of 140°, dissolves $\frac{1}{38}$th of its weight of this acid, and $\frac{1}{80}$th at the temperature of 55·5°. When heated it melts, and on cooling crystallizes in needles. When heated in a retort it is volatilized, and condenses on the upper part in long needles. It does not precipitate lime, barytes, or strontian water, nor the salts containing these alkaline earths. The alkalies dissolve it very well, and form with it neutral salts. It precipitates nitrate of silver, muriate of tin, sulphate of iron, nitrate and acetate of lead, and nitrate of mercury, but it does not precipitate sulphate of copper or sulphate of zinc.

Nitric acid has no action on it. It dissolves in alcohol. It does not alter the colour of sulphate of indigo, provided it is free from yellow bitter matter *. These properties show a strong resemblance between this acid and the benzoic, though it differs in several respects.

IX. Prussic acid.

It has been announced in the Philosophical Magazine, that Mr Porret, junior, has obtained an acid differing from the prussic in containing less oxygen, and which is converted into prussic acid by the addition of oxygen. He calls it *prussous acid.* It is a most deli-

* Nicholson's *Jour.* xxiii. 149.

cate test of the presence of silver, and precipitates iron red *. As these experiments have not yet been published, it is impossible to form any notion of their nature. If they prove accurate, they will demonstrate that oxygen is one of the constituents of prussic acid.

X. Pyrotaric acid.

THE observation made by Gehlen respecting this acid, mentioned in vol. ii. p. 353 of this Work, induced Fourcroy and Vauquelin to examine it again, and they have ascertained that it is not an empyreumatic acetic acid, as they had been led to suppose, but an acid possessed of peculiar properties, and entitled to rank as a species apart. They obtained it by distilling tartar in a retort, saturating the liquid obtained by means of carbonate of potash, and purifying the salt by repeated crystallizations and solutions. When this salt was mixed with diluted sulphuric acid, and subjected to distillation, it furnished, towards the end of the process, a white sublimate, which attaches itself to the whole surface of the retort in scales. This sublimate is pure *pyrotartaric acid.*

Its taste is extremely acid. When heated it melts, and sublimes in a white smoke, without leaving any residue. It dissolves readily in water, and crystallizes again when subjected to spontaneous evaporation. It does not precipitate acetate of lead nor nitrate of silver; but it precipitates nitrate of mercury. Some time after

* *Phil. Mag.* xxxiii. 409.

it has been mixed with acetate of lead, needleform crystals make their appearance. Chap. II.

When combined in excess with potash, no salt similar to tartar is formed. In this state it instantly forms a precipitate when dropt into acetate of lead. Pyrotartrate of potash is soluble in alcohol. It does not precipitate the salts of barytes and lime, as tartrate of potash does*.

XI. Zingiberic acid.

AN anonymous writer in Nicholson's Journal † has announced the formation of a new acid from ginger, to which he has given the name of *zingiberic acid*. An ounce of white ginger was infused for two or three days in six ounces of nitric acid. The mixture was then diluted with rather more than its bulk of water, and evaporated at 212°, till the smell of nitric acid was gone. Carbonate of lead was then added to saturation, and the solution filtered. A sufficient quantity of nitric acid to neutralize the lead was added, and the liquid again filtered.

By evaporating the liquor, an acid was obtained, similar in appearance to short white pieces of raw silk. It oxidizes zinc and iron, dissolves the alkalies and alkaline earths, and the oxides of zinc, iron, lead, and copper. It differs from most of the vegetable acids, in forming soluble salts with barytes and lime. It is not volatilized nor melted at the temperature of 212°. It is pretty soluble in water. Its combination with mag-

* *Ann. de Chim.* lxiv. 42. † Vol. xxiii. p. 384.

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nesia has a sweet taste. A more complete investigation will be necessary before the peculiar nature of this substance can be considered as fully established.

Chap. IV.—Sect. II. Ether.—Vol. II. p. 439.

Alcohol unites with all vegetable acids.

Thenard has ascertained by experiment, that none of the vegetable acids are capable of forming an ether, when distilled with alcohol, except the acetic; but that all of them are capable of combining with alcohol, and of forming with it a kind of oily compound, if they be mixed with alcohol, and with a portion of any of the powerful mineral acids, as the sulphuric or muriatic, and distilled. The oily compound is sometimes obtained in the receiver, sometimes it remains in the retort.

Two parts of benzoic acid were dissolved in four parts of alcohol, of the specific gravity 0·800, and the solution mixed with one part of concentrated muriatic acid. This mixture was distilled in a retort. No gaseous substances were disengaged. The first liquid that came over was a weak alcohol. The last liquid that came over contained the peculiar oily substance, which might be separated by means of water. A good deal of the same matter remained in the retort, and was deposited on cooling. When purified, by washing it with hot water, in which it is not sensibly soluble, it possesses the following properties:

Its colour is yellowish; it is a little heavier than water; its taste is strong; it melts at the temperature of 80° or 86°, is volatilized at the temperature of 176°; is

acid, oily, scarcely soluble in cold water, more soluble in boiling water, but precipitates as the liquid cools; very soluble in alcohol, from which it may be precipitated by water. When deprived of the excess of benzoic acid by an alkaline carbonate, it became colourless, and remained liquid at the common temperature of the atmosphere; its other properties remained the same. When long agitated with caustic potash, it was decomposed, and found to be a compound of benzoic acid and alcohol.

A mixture of 30 parts oxalic acid, 36 alcohol, and 10 of sulphuric acid, being distilled till sulphuric ether begins to come over, the liquid in the retort, when diluted with water, deposited a similar oily matter, which was a compound of oxalic acid and alcohol. Citric and malic acids being substituted for oxalic, a similar oily compound was obtained. Tartaric acid furnished also an oily compound, but its properties were peculiar. Traces of a similar compound were observed when gallic acid was employed. The other vegetable acids were not tried; but it is probable that they also would furnish similar compounds: so that alcohol seems to have the property of combining with almost all the acids, and of neutralizing them, and concealing their characteristic properties.

When concentrated sulphuric acid is added to a mixture of acetic acid and alcohol, it greatly facilitates the formation of acetic ether. Nitric and muriatic acids produce the same effect, but a greater proportion of them is necessary. Phosphorous acid likewise produces a considerable effect, and arsenic and oxalic acids a still less. Tartaric and phosphoric acids produce no effect whatever. Thus it appears that acids favour the form-

Book II. Division III.

ation of acetic ether in proportion as they hav[e the]
property of condensing alcohol *.

Thenard has endeavoured to show that all animal [and]
vegetable substances have the property of combi[ning]
with acids, and of neutralizing them. He has pro[du-]
ced five examples from vegetable bodies, and as m[any]
from the animal kingdom. His hypothesis is ingeni[ous,]
though he has probably stretched it a great deal [too]
far †.

Book II.—Division III.—Chap. III. Salts. Vol. II. p. 565.

Several valuable analyses of different salts have [ap-]
peared since this Chapter was printed. The follow[ing]
Tables include the most material of these:

Muriate of Potash.

	‡	§
Acid	34·83	33·34
Base	65·17	66·66
Total	100	100

* *Mem. d'Arcueil*, ii. 5. † Ibid. ii. 23.
‡ Curaudau, *Jour. de Phys.* lxvii. 11.
§ Berthollet, *Mem. d'Arcueil*, ii. 55.

Muriate of Soda.

	*	†
Acid	46	43
Base	54	57
Total	100	100

Muriate of Ammonia.

61·65 acid
38·35 base

100 ‡

Muriate of Magnesia.

56·01 acid
43·99 base

100 §

Muriate of Lime.

49·23 acid
50·77 base

100 ||

* Dr Marcet, Nicholson's *Jour.* xx. 30.

† Berard, *Ann. de Chim.* lxxi. 63.

‡ Gay Lussac, *Mem. d'Arcueil*, ii. 253. His method was the same as mine; but I fell into an error, from not knowing the quantity of water in muriatic acid gas.

§ Marcet, Nicholson's *Jour.* xx. 29.

|| Ibid.

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Phosp

1

Carbo

1

Subcar

1

Carb

1

* Berthollet, *Mem. d'Ar*
† Berard, *Ann. de Chim.* l
§ Id. Ibid. p. 55.

Subcarbonate of Soda.

	*	*	‡
Acid	13·98	37·47	16·04
Base	23·33	62·53	20·85
Water	62·69		63·61
Total	100	100	100

Carbonates of the Alkaline Earths.

BERTHOLLET has rendered it probable, that what are considered at present as carbonates of the alkaline earths, are in reality subcarbonates; and that the true carbonates, if they could be formed, would contain twice as much acid, united to the same quantity of base, as the known carbonates §.

Sulphate of Potash.

	‖	¶	**
Acid	41·50	42·29	42·76
Base	58·50	57·71	57·24
Total	100	100	100

* Berard, *Ann. de Chim.* lxxi. 55 and 58.
‡ D'Arcet, Ibid. lxviii. 178, and lxxi. 208.
§ *Mém. d'Arcueil*, ii. 478. ‖ Berthollet, Ibid. p. 60.
¶ Curaudau, *Jour. de Phys.* lvii. 10.
** Berard, *Ann. de Chim.* lxxi. 47.

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Sulphate of Soda.

22·78 acid
47·22 base

100·00 *

Sulphate of Barytes.

32·30 acid
67·70 base

100·00 †

Nitrate of Potash.

	‡	§	‖
Acid	48·62	50·24	51·36
Base	51·38	49·76	48·64
Total	100	100	100

Phosphates.

It has been the opinion of chemists, that the only phosphates which can be decomposed by heat and charcoal, are the phosphate of ammonia and the metallic

* Berard, *Ann. de Chim.* lxxi. 54.
† Berthollet, *Mem. d'Arcueil*, ii. 49.
‡ Id. Ibid. p. 59.
§ Curaudau, *Jour. de Phys.* lxvii. 10.
‖ Berard, *Ann. de Chim.* lxxi. 68.

phosphates. Saussure junior has shown that this opinion is erroneous. By distilling a mixture of phosphate of potash and charcoal, and phosphate of soda and charcoal, in a strong heat, he obtained a considerable quantity of phosphorus. Even phosphate of lime was decomposed by the same process, but a very violent temperature was necessary *.

Sulphate of Copper.

PRIEUR has observed, that the sulphate of copper, when sufficiently transparent, refracts doubly, like many other crystals of a similar form †.

BOOK III.—CHAP. II.—SECT. II. MIXTURE OF GASES. Vol. III. p. 453.

THE experiments of Mr Dalton upon the rapidity with which gases mixed when brought into contact, have been repeated with care by Berthollet. His apparatus consisted of two small globular glass vessels, furnished each with a stopcock; the capacity of the first was 1·591 cubic inches, that of the second 1·693 cubic inches. They were joined by a tube 0·197 inch in diameter, and 10·43 inches long. The experiments were made in a cellar, where the temperature was equable. The stopcocks were kept shut, and all communication prevented, till the vessels had acquired exactly the same

* Ann. de Chim. lxv. 189.

† Ann. de Chim. lxvi. 188.

Book III. temperature. The stopcocks were then opened, the proper precautions not to alter the temperatur the end of the experiment, the stopcocks were and the gases in each vessel examined. The foll table exhibits the result of these experiments.

Glass vessels.	Gases used.	Time.	Gases found in ea
1 2	Hydrogen Carbonic acid	48 hours	41·73 Car. a 43·26 Ditto
1 2	Hydrogen Air	48 hours	47·24 Hydro 47·62 Ditto
1 2	Hydrogen Carbonic acid	24 hours	43 Carbonic 46 Ditto
1 2	Air Carbonic acid	24 hours	28 Carbonic 56 Ditto
1 2	Air Carbonic acid	24 hours	27·2 Carboni 59·8 Ditto
1 2	Azotic Oxygen	24 hours	60 Oxyge 39·33 Ditto
1 2	Hydrogen Oxygen	24 hours	50 Oxygen 50 Ditto
1 2	Hydrogen Azotic	24 hours	46 Hydrogen 45 Ditto
1 2	Azotic Carbonic acid	24 hours	22 Carbonic 60 Ditto
1 2	Azotic Carbonic acid	48 hours	35 Carbonic 61 Ditto

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Glass vessels.	Gases used.	Time.	Gases found in each vessel.
1	Oxygen	24 hours	24 Carbonic acid
2	Carbonic acid		60 Ditto
1	Air	17 days	42 Carbonic acid
2	Carbonic acid		50 Carbonic acid

From these experiments it appears, that the gases mix more speedily when one of them is hydrogen, and much more slowly when that gas is wanting. In the last experiment we see, that 17 days were not sufficient to produce an equable mixture of air and carbonic acid *. It is unnecessary to observe, how incompatible these results are with Mr Dalton's hypothesis of the non-elasticity of different gases with respect to each other.

Sect. III. Combination of Gases. Vol. III. p. 467.

Gay Lussac has published an ingenious essay † on the combination of gases, in which he has endeavoured to show, that they always combine either in equal bulks, or one part of one, by bulk, with two or with three parts of the other. Though he appears to me to have carried his generalization rather too far, yet it must be allowed, that in a good many of the cases he has made out his point. The following table exhibits

* *Mem. d'Arcueil*, ii. 463. † Ibid. ii. 207.

As the specific gravities of the different gases which Gay Lussac employed, differ a good deal from some of those which I have given, I think it necessary to add them here, together with the names of the philosophers who made the experiments. At the same time, I do not consider them as so correct as those which I have given in the table, Vol. III. p. 439, of this work.

Gases.	Sp. gravities.	Authorities.
Air	1·00000	Biot and Arrago
Oxygen gas	1·10359	Biot and Arrago
Azotic gas	0·96913	Biot and Arrago
Hydrogen gas	0·07321	Biot and Arrago
Carbonic acid gas	1·51961	Biot and Arrago
Ammoniacal gas	0·59669	Biot and Arrago
Muriatic acid gas	1·278	Biot and Gay Lussac
Nitrous oxide	1·61414	Davy
	1·36293	Berthollet
Nitrous gas	1·0388	Berard
Sulphurous acid gas	2·265	Kirwan
Carbonic oxide	0·9569	Cruickshanks
Steam	0·6896	Trales
Oxymuriatic acid gas	2·470	Thenard & Gay Lussac

PART II.—BOOK I.—CHAP. I.—SECT. I. AIR. Vol. IV. p. 6.

GAY LUSSAC has published some observations upon the nitrous gas eudiometer, which differ very much from those of Dalton, stated in p. 14 of this section. According to Gay Lussac, oxygen gas combines with two proportions of nitrous gas, either with twice or

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with thrice its bulk of it. When the oxygen predominates, the compound formed consists of one part oxygen, and two parts nitrous gas; when the nitrous gas predominates, the compound formed consists of one part oxygen, and three parts nitrous gas. To analyse air, let up 100 measures of it into a wide vessel; add 100 measures of nitrous gas; do not agitate. In about a minute the absorption is complete. Measure the residue. One fourth of the bulk absorbed gives the oxygen gas in the air examined *. I have repeated this experiment, and find, that unless the vessel be 3 inches in diameter, the result is very inaccurate. Even then, one fourth of the bulk absorbed hardly equals the quantity of oxygen in the air. Hence it is obvious that a vessel of 5 or 6 inches in diameter is necessary to ensure an approach to correct results, when the experiment is made in that way.

Part II.—Book I.—Chap. II.—Sect. VI. Meteoric Stones. Vol. IV. p. 119.

In the account of the constituents of meteoric stones, it was omitted to mention, that Laugier has detected chromium as a constituent of them, and that this substance has been found in small quantities in most meteoric stones analysed since that discovery was announced.

Sage affirmed, that he had discovered alumina as another constituent; but when Vauquelin repeated the

* *Mem. d'Arcueil*, ii. 235.

experiment, he could only find minute traces of that earth. But a meteoric stone, which fell lately in Moravia, and which has the common characters of other meteoric stones, has been found to possess different constituents. The following is the analysis of it by Vauquelin. Chap. II.

Silica	50
Lime	12
Alumina	9
Oxide of iron	29
Oxide of manganese	1
Nickel, a trace	
Sulphur, an atom	
	101 *

The presence of lime and alumina, and the absence of magnesia and chromium, distinguish this stone from all others formerly examined, and constitute it a species apart.

PART II.—BOOK III. MINERALS. Vol. IV. p. 181.

A CONSIDERABLE number of new chemical analyses of minerals have been recently published, chiefly by Klaproth. I shall here insert the most important of these, following the order in which the minerals themselves have been arranged.

* *Ann. de Chim.* lxx. 321.

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Cinnamon Stone.

Silica	38·80
Alumina	21·20
Lime	31·25
Oxide of iron	6·50
Loss	2·25
	100·00 *

From this analysis it is obvious, that cinnamon stone is improperly classed with zircon and hyacinth. Professor Jameson had previously placed it in the garnet family, considering it as the hyacinth originally analysed by Bergman.

Augite of Frascati.

Silica	48·00
Lime	24·00
Magnesia	8·75
Alumina	5·00
Oxide of iron	12·00
Oxide of manganese	1·00
Loss	1·25
	100·00 †

* Klaproth. *Ann. de Chim.* lxv. 186. † Id. Ibid. lxvii. 225.

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The specific gravity of the specimen was 3·400. This analysis corresponds with the preceding, except in the proportion of lime, which is greater.

	Green-land Garnet.	Melanite of Frascati.	Granatite.	
	*	†	‡	‡
Silica	43·00	35·50	37·50	27·00
Alumina	15·50	6·00	41·00	52·25
Lime	1·75	32·50		
Magnesia	8·50		0·50	
Iron oxide	29·50	24·25	18·25	1 ·50
Manganese oxide	0·50	0·40	0·50	0·25
Loss	1·25	1·35	2·25	2·00
	100·00	100·00	100·00	100·00

Schorlite.

	§	‖
Silica	36·8	43·0
Alumine	52·6	49·5
Lime	3·3	
Oxide of iron		1·0
Fluoric acid	5·8	4·0
Water	1·5	1
Loss		1·5
	100·0	100·0

* Klaproth, *Ann. de Chim.* lxv. 186.
† Id. Ibid, lxvii. 233. Sp. gr. 3·7
‡ Id. Ibid. p. 235. First variety black, second red.
§ Vauquelin, Ibid. lxvii. 247. ‖ Klaproth, Ibid. p. 250.

Part II.

	Quartz crystals.	Amorph. Quartz.	Prase.	Iron flint.		
	*	*	*	†	†	†
Silica	99·37	97·75	98·5	92·00	93·5	76·00
Alumina	0·63‡	0·50‡	0·5			0·25
Oxide of iron			1·0	5·75	5·	21·50
Ox. of man.				1·00		
Water		1·00		1·00	1·	1·00
Loss		0·75		0·25	0·5	1·25
	100·	100·	100·	100·	100·	100·

Mica.

	§	§	§
Silica	47·00	48·00	42·5
Alumina	20·00	34·25	11·5
Magnesia		0·50	9·0
Oxide of iron	15·50	4·50	22·0
Oxide of manganese	1·75		2·0
Potash	14·50	8·75	10·0
Water		1·25	1·0
Loss	1·25	2·75	2·0
	100	100	100

* Bucholz. *Ann. de Chim.* lxx. 49.

† Id. Ibid. p. 53. The first variety brown, the second yellow, the third red.

‡ A mixture of alumina and oxide of iron.

§ Klaproth, *Ann. de Chim.* lxx. 98, 113, and 120. The first specimen was common mica, the second broad-leaved mica from Siberia, the third black mica from Siberia.

Book III.

Labradore Hornblende.

54·25	silica
2·25	alumina
1·50	lime
14·00	magnesia
24·50	oxide of iron
1·00	water
2·50	loss
100·00 *	

y has lately made this mineral a distinct species, h he distinguishes by the name of *hyperstene*.

	Common Talc.	Scaly Talc.
	†	‡
Silica	62·00	
Alumina		81·75
Lime		4·00
Magnesia	30·50	0·75
Oxide of iron	2·50	
Potash	2·75	0·50
Water	0·50	13·50
Loss	1·75	
	100·00	100·50

rom these analyses it is obvious, that these two mi-ls ought to be separated from each other, and no er considered as belonging to the same species.

Klaproth, *Ann. de Chim.* lxvii. 241. † Id. Ibid. lxx. 100.
John, Ibid. lxvii. 259.

Part II.

	Calcareous Spar.	Arragonite.
	*	*
Lime	56·327	56·351
Carbonic acid	43·045	42·919
Water	0·628	0·730
	100·000	100·000

Capillary Pyrites.

Klaproth has analysed this ore, and found it native nickel with some cobalt and arsenic. It must, of course, be separated from iron pyrites, with which it has no connection †.

Sulphate of Cobalt.

The mineral described under this name, in Vol. IV. p. 507, it appears, is rather a sulphate of magnesia mixed with oxide of cobalt. But real sulphate of cobalt has been lately found at Bieber in the county of Hanau. It is thus described by Kopp.

Colour flesh red, passing to rose red and carmine red. Sometimes dendritiform, and sometimes in thin layers on other minerals. Lustre usually 0, sometimes 2, silky. Fracture earthy. Opaque. Streak reddish white. Soft. Light. Taste styptic. It occurs cover-

* Thenard and Biot, *Mem. d'Arcueil*, ii. 176.
† *Ann. de Chim.* lxv. 186.

-ing sulphate of barytes, along with other ores of cobalt. Its constituents are,

38·71	oxide of cobalt
19·74	sulphuric acid
41·55	water
100·00 *	

Needle Ore.

THIS mineral has been erroneously arranged among the ores of chromium. It ought to be placed among the ores of bismuth, as is obvious from the following analysis of Dr John.

43·20	bismuth
24·32	lead
12·10	copper
1·58	nickel?
1·32	tellurium?
11·58	sulphur
5·90	loss
100·00 †	

Aplome.

THIS is the name given by Hauy to a mineral found in Siberia, on the borders of the river Lena. It has some resemblance in its crystallization to the garnet and the vesuvian. Its crystals are dodecahedrons,

* Ann. de Chim. lxx. 55. † Ibid. lxvii. 278.

Part II.

formed from a cube by a decrement of one range on each edge. Colour reddish brown. Very hard. Breaks into crystalline fragments, with difficulty reduced to powder. Specific gravity 3·444. According to the analysis of Laugier, it is composed of

40·0	silica
20·0	alumina
14·5	lime
14·5	oxide of iron
2·0	oxide of manganese
2·0	mixture of silica and iron
2·0	loss by calcination
5·0	loss
100·0 *	

Bronzite.

This mineral has been classed by Hauy as a variety of smaragdite, under the name of *lamello-fibrous diallage*. It occurs in serpentine near Kranbat in the Upper Stiria, in large masses, and has been observed in other places disseminated in serpentine.

Colour tombac brown. Massive and disseminated. Lustre 4, semimetallic. Fracture lamellar, with a single cleavage. In distinct granular concretions. Transparency 2; in large masses 0. Streak white. Semihard. Very brittle. Specific gravity 3·200. According to the analysis of Klaproth, its constituents are as follows:

* *Jour. de Phys.* lxvii. 307. *Ann. de Chim.* lxxi. 110.

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60·0 silica
27·5 magnesia
10·5 oxide of iron
0·5 water
1·5 loss

100·0 *

PART II.—BOOK IV.—CHAP. II.—SECT. V.
LEAVES. Vol. V. p. 223.

Tobacco.

VAUQUELIN has lately published an elaborate analysis of the leaves of the different species of *nicotiana*, chiefly the *latifolia*. The expressed juice contained the following substances:

1. A considerable quantity of albumen.
2. Supermalate of lime.
3. Acetic acid.
4. A notable quantity of nitrate and muriate of potash.
5. A red matter soluble in alcohol and water, which swells considerably when heated.
6. Muriate of ammonia.
7. A peculiar substance, to which tobacco owes its properties. This substance is colourless, acrid, volatile, soluble in water and in alcohol, and seems different from every vegetable principle hitherto described. It seems to approach the volatile oils in many of its properties.
8. Green fecula, composed, as usual, chiefly of gluten, green resin, and woody fibre †.

* Ann

† Ibid. lxxi. 139.

Part II.

Part II.—Book V. Animal Substances, Vol. V. p. 428.

Berzelius has published a variety of results which he obtained by analysing animal substances. The following are the most important of these.

1. Muscular flesh contains an uncombined acid. This acid is combustible, and analogous to the malic. All the alkali contained in the liquor extracted from muscle, is saturated with this acid.

2. The fibrin and coagulable part of blood, he considers as the same substance in different states. Iron is the colouring matter of blood, but not phosphate of iron. Blood contains no gelatine, but some is formed when the blood is long boiled.

3. The acid of milk, in his opinion, is not the acetic acid.

4. He could not succeed in analysing bile by the process of Thenard. What is called resin of bile he considers as not entitled to the name of resin *.

Niccolanum.

I forgot to mention, in its proper place, that Hisinger and Gehlen have proved that niccolanum is a compound of nickel and cobalt, with a trace of iron and arsenic †.

* *Ann. de Chim.* lxxi. 218.

† *Jour. de Phys.* lxviii. 39.

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